ASSESSMENT OF BUS SYSTEM SERVICE AND PERFORMANCE FOR PUBLIC TRANSPORT IMPROVEMENT

SUWARDO

DOCTOR OF PHILOSOPHY
CIVIL ENGINEERING DEPARTMENT

UNIVERSITI TEKNOLOGI PETRONAS

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ASSESSMENT OF BUS SYSTEM SERVICE AND PERFORMANCE FOR

PUBLIC TRANSPORT IMPROVEMENT

by

SUWARDO

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ASSESSMENT OF BUS SYSTEM SERVICE AND PERFORMANCE FOR PUBLIC TRANSPORT IMPROVEMENT

by

SUWARDO

A Thesis

Submitted to the Postgraduate Studies Programme

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BANDAR SERI ISKANDAR,

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DECLARATION OF THESIS

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DEDICATION

Easiness may be given to those who strive to learn and teach.
Allah's blessing may be given to those who do research and write for the life.

To my parents with their moral and dedication:
Giman Wignyosuharjo and Sugiarsi

To my parents-in-law with their support and help:
Sunardi and Kardijanti

To my wife with her love and patient:
Ety Dwiastuti

To my children with their spirit and wishes:
Amalia Khoirunnisa and Abyasa Pradhipta

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ABSTRACT

This study, entitled "Assessment of Bus System Service and Performance for Public Transport Improvement" was based on a case study of bus service at the Ipoh-Lumut corridor in Perak, Malaysia. This corridor is serviced by stage buses in mixed traffic. The problems faced are low quality of buses, inconvenience, long waiting time, limited facilities, low reliability and low passengers loading which have caused the system to be unattractive to passengers. The purposes of the study were to analyze bus service characteristics and performance of the bus system, to assess bus service reliability and to formulate strategies for the improvement of bus service performance.

A fieldwork investigation was conducted covering preliminary survey, primary data survey and secondary data collection. The primary data consisted of bus service operation and passenger boarding and alighting. The approaches of study included description of study area, analysis of bus service characteristics, performance, improvement strategies, evaluation of ridership factors elasticity and sensitivity of bus service demand. Bus service characteristics were analyzed based on fundamental theory, World Bank Standard and TCQSM Standard. In addition, statistical methods such as ANOVA, MARE, MAPPE, ARIMA, MLR and SNN model were applied. The proposed performance indicators to evaluate bus service quality and reliability comprised of on-time performance, regularity, punctuality and waiting time. The concept of elasticity and sensitivity were explored to evaluate bus service demand with respect to ridership factors changes. Finally, gravity model was calibrated to estimate passenger trip distribution by using data of passenger boarding and alighting.

From this study, it was concluded that the improvement of bus service quality and performance can be done by changing of frequency, the capacity of passenger and improving the bus service reliability. Based on the elasticity analysis, in the service characteristics category, travel time was an elastic factor, whereas ticket fare, fuel price, per capita income, frequency and headway were inelastic factors in the bus

service demand. Meanwhile, in the service reliability category, the punctuality, waiting time, regularity and on-time performance were categorized as elastic factors. Moreover, the bus service demand increased by changes of factors such as the increase in punctuality, decrease in waiting time, increase in level of service and increase in regularity.

ABSTRAK

Kajian ini bertajuk "Sistem Penilaian Perkhidmatan Bas dan Prestasinya untuk Meningkatkan Kemudahan Pengangkutan Awam" yang berasaskan pada kajian kes perkhidmatan bas di koridor Ipoh-Lumut di Perak, Malaysia. Koridor ini mempunyai perkhidmatan bas berhenti-henti dalam lalu lintas yang pelbagai. Masalah yang dihadapi yang menyebabkan sistem menjadi tidak menarik bagi penumpang adalah kualiti bas yang rendah, keadaan bas yang tidak selesa, masa menunggu bas yang lama, kemudahan yang terhad, kebolehpercayaan perkhidmatan yang rendah dan bilangan penumpang yang rendah. Objektif kajian ini adalah untuk menganalisa ciri-ciri perkhidmatan dan prestasi perkhidmatan bas, menentukan kebolehpercayaan perkhidmatan dan merumuskan strategi bagi meningkatkan prestasi perkhidmatan bas.

Penyelidikan lapangan dilakukan yang meliputi kajian awal, kajian data utama dan pengumpulan data tambahan. Data utama terdiri daripada operasi perkhidmatan bas dan bilangan penumpang naik dan turun. Pendekatan kajian merangkumi keterangan daerah kajian, analisis ciri-ciri perkhidmatan bas, prestasi, strategi pembaikan, penilaian elastisiti daripada faktor-faktor permintaan penumpang dan sensitiviti permintaan perkhidmatan bas. Ciri-ciri perkhidmatan bas yang dianalisa adalah berasaskan kepada teori, rujukan Bank Dunia dan manual TCQSM. Selain itu, kaedah statistik seperti ANOVA, MARE, MAPPE, ARIMA, MLR dan SNN telah digunapakai. Penunjuk-penunjuk prestasi yang dicadangkan untuk menilai kualiti perkhidmatan bas dan kebolehpercayaan perkhidmatan bas terdiri daripada prestasi ketepatan masa perkhidmatan, keteraturan perkhidmatan, ketepatan masa perjalanan dan waktu menunggu bas. Konsep elastisiti dan sensitiviti dieksplorasi untuk menilai permintaan perkhidmatan bas berhubung dengan perubahan faktor permintaan penumpang. Akhirnya, model graviti telah dikalibrasi atau diubah suai untuk menganggarkan pembahagian penumpang mengikut perjalanan dengan menggunakan data daripada bilangan penumpang naik dan turun.

Dari kajian ini dapatlah disimpulkan bahawa peningkatan kualiti perkhidmatan bas dan prestasinya boleh dilakukan dengan mengubah frekuensi bas, keupayaan dan meningkatkan kebolehpercayaan perkhidmatan bas. Berdasarkan analisis elastisiti, dalam kategori ciri-ciri perkhidmatan, masa perjalanan merupakan faktor elastik, sedangkan kadar tambang, harga minyak, pendapatan per kapita, frekuensi bas dan jarak waktu antara bas adalah faktor tidak elastik dalam permintaan perkhidmatan bas. Sementara itu, dalam kategori kebolehpercayaan perkhidmatan bas, ketepatan masa perjalanan, masa menunggu bas, keteraturan perkhidmatan dan ketepatan masa perkhidmatan dikategorikan sebagai faktor elastik. Selain itu, permintaan perkhidmatan bas akan meningkat adalah kerana perubahan faktor seperti peningkatan ketepatan masa perjalanan, penurunan masa menunggu bas, peningkatan tahap perkhidmatan bas dan peningkatan keteraturan perkhidmatan.

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β = density of public transport route (m/m^2)
A_j = total trip attracted to zone *j*,
BS_i = current bus stop
BS_{ij} = number of bus stop from bus stop *i*-th to *j*-th
BS_j = destination or target bus stop
BS_o = bus stop at origin of trip
C = capacity of vehicle or bus (seats)
CT = time of circulation (minute)
C_{vh} = coefficient of variation of headways
D = length of route (kilometer, km)
D_{ij} = distance from bus stop *i*-th to *j*-th in kilometer
DY_{oi} = delay from origin bus stop to current bus stop in minute
E = elasticity
F = frequency (bus per hour)
F_{ij} = friction factor for trip interchange *ij*,
Fv = factor of availability of vehicle (100%)
H = headway (minute)
i = origin zone number, i = 1, 2, 3, …, n,
I_{ij} = Number of intersection from current bus stop to target bus stop.
j = destination zone number, j = 1, 2, 3, …, n, and
K = number of vehicle or bus or fleet (bus)
K_{ij} = socioeconomic adjustment factor for interchange *ij* if necessary,
LF = load factor (percent, %)
n = number of zones in the study area.
P = maximum number of passengers at the point (passenger, pass)
P_1 = price before
P_2 = price after
P_I = punctuality index
P_i = total trip produced from zone *i*,
Q_1 = price before
Q_2 = price after
R_i = called the “production index” (a constant for each production zone *i*),
S = distance between bus stops or shelters (meter)
S_{max} = maximum walking distance (meter)
S_{oi} = average speed from origin to current bus stop (bus stop *i*-th) in km/h
T = travel time; length of route divided by operating speed (minute)
T_{ij} = number of trips produced in zone *i*, and attracted to zone *j*,
t_{ij} = travel time (or impedance) for interchange *ij*,
TT_{ij} = travel time from current bus stop to target bus stop in minute
V = operating speed (km/h)
$E_{(W)}$ = expected average waiting time

LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
APTA	American Public Transportation Association
ARIMA	Auto-Regressive Integrated Moving Average; the most general class of models for forecasting a time series which can be stationarized by transformations such as differencing and logging (http://www.duke.edu/)
BRT	Bus Rapid Transit
CBD	Central Business District
CPA	Central Planning Area (Perak State Structure Plan, 2020)
EPU	Economic Planning Unit
GDP	Gross Domestic Product
GPS	Global Positioning System (http://www.gps.gov/)
HPU	Highway Planning Unit; Division of Ministry of Works Malaysia
ITS	Intelligent Transportation System
JKJR	Jabatan Keselamatan Jalan Raya
JKR	Jabatan Kerja Raya, Division of Ministry of Works Malaysia (http://www.jkr.gov.my)
JPJ	Jabatan Pengangkutan Jalan (Road Transport Department)
KLCH	Kuala Lumpur Structure Plan
LOS	Level of Service
LPKP	Lembaga Pelesenan Kenderaan Perdagangan/Commercial Vehicle Licensing Board (CVLB); Devision of Ministry of Transport Malaysia (www.mot.gov.my)
MAPPE	Mean Absolute Percentage Prediction Error
MARE	Mean Absolute Relative Error
MBI	Majlis Bandaraya Ipoh
MLR	Multiple Linear Regression; MLR is a multivariate statistical technique for examining the linear correlations between two or more independent variables and a single dependent variable (http://en.wikiversity.org)
PDRM	Polis Diraja Malaysia (Royal Police Malaysia)
PLS	Partial Least Squares (PLS Multiple Regressions)
QOS	Quality of Service
RB	Regular Bus
RMSE	Root Mean Square Error
RTVM	Road Traffic Volume Malaysia; Division of Ministry of Work Malaysia (www.kkr.gov.my)
SNN	Statistica Neural Network (StatSoft, 2004)
TCQSM	Transit Capacity and Quality of Service Manual,
TCRP	Transit Cooperative Research Program; Devision of Transportation Research Board (TRB)
UPEN	Unit Perancang Ekonomi Negeri; (UPEN, 2004)
VTPI	Victoria Transport Policy Institute

PREFACE

This thesis entitled “Assessment of Bus System Service and Performance for Public Transport Improvement” is prepared to fulfill the requirement for degree of doctor of philosophy in Universiti Teknologi PETRONAS. The object of the thesis is bus system service at the Ipoh-Lumut corridor in Perak Malaysia. The current bus system is categorized as a regular stage bus which operated in the mixed traffic.

The purposes of study are to analyze the bus service characteristics and performance of current bus system, to assess the reliability of bus service and to formulate the strategies on the improvement of bus service performance. The study contribute to the body of knowledge in public transport planning, operation and management and contribute in providing approach of evaluation with practical solutions proposed for improving bus service quality. The study is rationally supported with adequate both primary and secondary data, critical analysis, theoretical and practical evaluation of alternative solutions. The advantages cover specifically for the current bus system service improvement and generally for the promotion of public transport use for reducing the private cars use in people mobility.

The readers are introduced with the logical thesis structure that consists of seven chapters. The thesis mainly contains chapter one of introduction, chapter two of literature review, chapter three of methodology, chapter four of description and profile of study area, chapter five of bus service characteristics and performances evaluation, chapter six of analysis of bus service improvement and chapter seven of conclusions and recommendations.

Suwardo

Bandar Seri Iskandar, August 2010

CHAPTER 1
INTRODUCTION

1.0 Overview

This chapter briefly explains the background of the research, problem statement, objectives of this study, research questions, the scope of research and limitation, research significances, advantages, operational problems during conducting the research and the structure or outline of thesis.

1.1 Background

Quality of bus service is an important factor to users in considering the mode of public transportation to use as an alternative for their mobility purposes. The quality of bus service determines how people would use public transportation when they are facing problem of ineffective and inefficient when using private cars for their working trip or other trip purposes.

In the location of study, Ipoh-Lumut corridor in Perak, Malaysia, current bus system has some problems such as low quality of busses, inconvenience of fleets, long waiting time and limited facilities. Long waiting time for passengers getting on bus is one amongst other low quality of bus services. In general, the actual problems are low reliability with long waiting time at bus stop and low passengers loading. In the current bus system, typical waiting time of more than 40 minutes may cause the system unattractive to passengers, thus passenger loading is low.

Ipoh-Lumut highway, a divided 4-lane 2-way highway recently completed, is expected to bring the increase in traffic flow compared to previous type of undivided 2-lane 2-way highway. This new type of highway geometric contributes to shorten travel time. The new wider highway may provide better opportunity to bus service with adequate space available for running on the lane or standing on bus stop. These situations are suitable and viable to support the improvement of bus service characteristics and performance indicators.

Mixed traffic at which bus service is provided often causes an increase of bus travel time. Bus travel time and delay increase sharply in the congested traffic while heavy truck is blocking the vehicle behind. Heavy traffic volume in the mixed traffic may block vehicles for overtaking, thus traffic delay increases sharply.

Low passenger loading is experienced by the existing bus service, thus revenue is low. Therefore, there is difficulty for bus operators to allocate capital for renewing bus fleets. The old bus fleets often have engine trouble or other problems during operation. Operators generally take more time for recovering the engine trouble or other problems until the arrival of another bus to serve passengers by taking over the old bus's service.

1.2 Problem Statement

Bus service at the Ipoh-Lumut corridor in Perak, Malaysia is stage buses in mixed traffic. The problems faced are low quality of buses, inconvenience, long waiting time, limited facilities, low reliability and low passengers loading which cause the system to be unattractive to passengers. The purposes of study were to analyze bus service characteristics and performance of bus service, to assess bus service reliability and to formulate strategies for the improvement of bus service performance. Current bus system is not a preferred choice as many people are not attracted to use the bus service. Many have experienced long waiting time for getting on the bus at the location of study. In fact, the loading of passengers per bus trip is low. The low occupation is similarly confirmed by the relevant operator of bus service. Meanwhile, driving private car is preferred by many people for daily activities, whether for working purpose or non-working purpose.

In addition, the sustainable integrated development, operational strategic management planning, comprehensive rules and local government policies of the public transportation management had not been developed adequately. Therefore, the bus operators faced difficulties for improving their bus service, for instance, difficulty to replace the old bus fleets with new ones. These further contribute to the low number of passengers using bus service and the quality of bus service is not attractive to passengers (e.g. long waiting time).

1.3 Objectives

Based on the problems mentioned above, the study or research at the respective location is proposed. There are two main objectives for overcoming the problems to be reached at the end of study as follows:

1. to analyze and evaluate the bus service characteristics and performance indicators of current bus system and
2. to assess the operation reliability of bus service and formulate the strategies proposed for improving the quality of bus service and performance.

The first objective is further detailed with a number of targets as follow:

1. to evaluate operational conditions and bus service characteristics of current bus system,
2. to analyze the bus service characteristics and performance indicator and
3. to compare performance indicators with viable standard or relevant manual.

The second objective includes targets as follows:

1. to arrange some possible alternatives of operational strategies for bus service improvement,
2. to determine and to choose the criteria of decision making on the improvement strategy,
3. to evaluate and assess the appropriate strategy for improvement of bus service quality and performance indicators (reliability) and
4. to assess elasticity of ridership factors and sensitivity of bus service demand.

1.4 Research Questions

Several research questions are defined to assist in fulfilling the objectives presented in the previous section. In addressing the analysis and evaluation of current bus system characteristics, performance indicators and also the assessment of strategies proposed for bus service improvement, the following research questions are presented:

1. What are the kinds of measurements of characteristics of the existing bus service?
2. How can the characteristics and performance indicator of bus service be analyzed and evaluated?
3. How can the performance indicators be compared to standard of performance?
4. What are the kinds of alternative strategies needed to improve bus service regarding the state of existing bus service?
5. What are the kinds of criteria applicable for making decision on the improvement of bus service quality and reliability?
6. How can the appropriate strategy in improving bus service based on the existing ridership factors and bus service demand sensitivity be evaluated?

1.5 Scope of Research and Limitation

The scope of study is specified based on the limitations or applicability of some aspects. In this section, the detailed account of the scope is given. The emphasis is given to the technical aspects in the analysis and discussion. Thus, research was limited to the following:

1. certain corridor of bus services were determined,
2. technical aspects of bus service were focused,
3. planning and management of bus service were more emphasized,
4. economical and policy aspects were not discussed in detail and
5. the standards of bus operation available and other relevant manuals were referred with some adjustments to local pattern.

1.6 Research Significance and Contribution

Data were collected from the respective location of study. Some methods of analysis were adapted from the theoretical background, relevant standard and manual. Local assets and available equipment were optimally used for this study because there was no control device implemented at the bus service and there were a few previous studies about conventional regular bus operation. The factual findings include bus service characteristics in mixed traffic, bus service demand analysis, bus service improvement strategy, sensitivities of bus service demand, model of bus service demand, measurements and indicators of improvement and trip distribution analysis. The strategy of bus service improvement, assessment on ridership factors and the sensitivity of bus service demand are discussed and evaluated.

The significance of results includes some models used in bus travel time predicition, the explorative performance indicators (on-time performance, regularity, punctuality and average waiting time), applicable concept of elasticity and sensitivity to assess strategies of improvement in short term period and the the calibrated gravity model for bus passenger trip distribution. Those results lead to a potential to develop a comprehensive framework for evaluation of bus service planning and management. The results contribute to the body of knowledge on public transportation planning, operation and management. Additionally, this contributes in providing approach of evaluation with practical solutions proposed for improving bus service quality.

1.7 Research Advantages

The research advantages cover a number of aspects as follows:

1. The results of research can be useful outcomes for public transportation improvement and for the development of transportation, environment and economic. The government and the bus operator will benefit.
2. The advantages of research include the proposed improvement to improve public transportation mode based on bus service as an alternative transportation for people mobility. Users are provided with viable and affordable bus service.

3. On environmental aspect, the research benefits to minimize fuel consumption, gas emission and noise due to improving bus service quality and performance (reliability). The operators and users will benefit.
4. In the economic aspect, the research outcomes will benefit in minimizing transport cost by resource sharing of using public transportation (efficiency) and in maximizing revenue of bus operation due to more passengers. The government, the operators and users will also benefit.

1.8 Operational Problems

The operational problems in conducting the research are as follows:

1. uncontrollable circumstances during the on board data measurement (e.g. modal shift, bus fleet engine trouble, postponed departure and noise), and
2. incomplete secondary data required extrapolation (i.e. bus service timetable).

1.9 Structure of Thesis

The structure of thesis is presented mainly into seven chapters. Prior to the body of thesis, there are some preliminary pages such as acknowledgement, abstract, list of table, list of figures, list of symbols and abbreviation. At the end of the thesis, the references, glossary of terms and appendices are presented. Paragraphs below describe the structure of the thesis.

Chapter 1 Introduction. This chapter addresses research background, problems, objectives of this study, research questions, scope and limitation, solution approach, research significances, advantages, operational problems and the outline of the thesis.

Chapter 2 Literature Review. This chapter briefly discusses the background of research, related previous works or investigations, relevant previous study, the standard of bus service and other relevance manual, theoretical and practical knowledge or background and solution approach on how this research works will be performed. In fact, low service quality of current regular stage bus, lack of data measurements and inadequate standard or evaluation framework encourage the study on the bus system service. Therefore, further study in proposing solution approaches and their measures of effectiveness are presented such as bus service characteristics analysis, performance indicators evaluation and improvement, bus service demand analysis and trip distribution of bus service demand.

Chapter 3 Methodology. This chapter presents the method chosen in running the research. Study approach and method of analysis are proposed based on theory provided in the literature or theoretical background. The standard of bus service and relevant manual, details of data resources, location of study, time of survey, surveyor and data instruments, procedure of survey and method of analysis and evaluation are briefly presented. Flow diagram or flowchart is also used to describe the whole process of research.

Chapter 4 Description and Profile of Study Area. This chapter presents the data compilation of secondary data, statistical descriptive analysis and results discussion. Discussion on the subject of analysis is performed with graph or table complimentary. Secondary data are analyzed and presented for completing the analysis of primary data in the next chapter. Theory, formulation and analysis based on methodology from Chapter 3 are implemented accordingly.

Chapter 5 Bus Service Characteristics and Performance Evaluation. This chapter presents the results of study and the discussion on related results with regards to the objectives. This chapter contains compiled data analysis, analysis of bus characteristic, bus service performance, evaluation indicators and bus travel time prediction. The bus service performances discussed include on-time performance, service regularity, punctuality index and expected average waiting time. Bus travel time prediction is also discussed.

Chapter 6 Analysis of Bus Service Improvement. This chapter discusses quantitative analysis to assess strategy for the bus service improvement. The discussions include bus service demand analysis, bus service improvement strategy, sensitivities of bus service demand, model of bus service demand, measurements and indicators of improvement and trip distribution analysis. The strategies for bus service improvement are discussed and evaluated. The assessment on ridership factors elasticity and the sensitivity of bus service demand are also performed.

Chapter 7 Conclusions and Recommendations. This final chapter concludes the whole results of study and highlighting factual findings and contributions followed by recommendations on future work and limitation of research work.

1.10 Summary

Chapter one as presented above contains background, problems, objectives, scope of research work and limitation, research significances and contributions, operational problems faced and structure of thesis. Those are the important guidelines in introducing the main contents of thesis.

CHAPTER 2
LITERATURE REVIEW

2.0 Overview

This chapter begins with the detail background of research and the description of knowledge in bus system service both theoretical and practical aspects. Through description and review of the related literature or theoretical background, the strategic approaches in planning and operational redesigning of services are assessed for implementation. The detail discussion is focused on a number of aspects, including the identification of the problem in bus service, measurements of bus service quality, a series of strategic improvement to perform a better bus system service, selected performance indicators evaluation and improvement, bus service demand analysis and trip distribution of bus service demand.

2.1 Accessibility and Transportation Option

There are some important elements of transport in improving public transportation system. Their description and current consideration have been studied by Victoria Transport Policy Institute [1]. The main elements such as transport demand, basic access and mobility, mobility and transportation option, are discussed in Table 2.1. In this discussion, the transportation options which provided some transport modes supporting the public transportation are included such as walking, cycling, ridesharing, transit, taxi, delivery services and telecommunications. Their quality of service is determined by some factors such as availability, speed, frequency, convenience, comfort, safety, price and prestige.

By comparing many transportation modes based on characteristics of movement (speed) and accessibility, bus is a kind of passenger transportation modals which operates at low to high speed but at medium accessibility as described in Figure 2.1. Local bus can provide service at medium accessibility with relatively low speed, meanwhile the express bus operates at high speed with medium accessibility.

Table 2.1 Description of public transportation improvement

No.	Name	Description	Current consideration
1.	Transport demand	The amount of mobility and access that people and businesses would choose under various conditions (times, prices, levels of service, etc).	Motorized travel demand is well studied, but nonmotorized demand is not. Travel demand is often treated as inflexible rather than variable.
2.	Basic access and mobility	The relatively high importance to society of some mobility and accessibility activity.	Considered in some types of planning such as special mobility services.
3.	Mobility	The distance and speed of travel, including personal mobility (measured as person-miles) and vehicle mobility (measured as vehicle-miles).	Conventional transport planning focuses primarily on mobility, particularly vehicle mobility.
4.	Transportation options	The quantity and quality of access options, including walking, cycling, ridesharing, transit, taxi, delivery services and telecommunications. Qualitative factors include their availability, speed, frequency, convenience, comfort, safety, price and prestige.	Motor vehicle options and quality are usually considered, using indicators such as roadway Level-of-Service, but other modes lack such indicators and some important service quality factors are often overlooked.

Source: Victoria Transport Policy Institute [1]

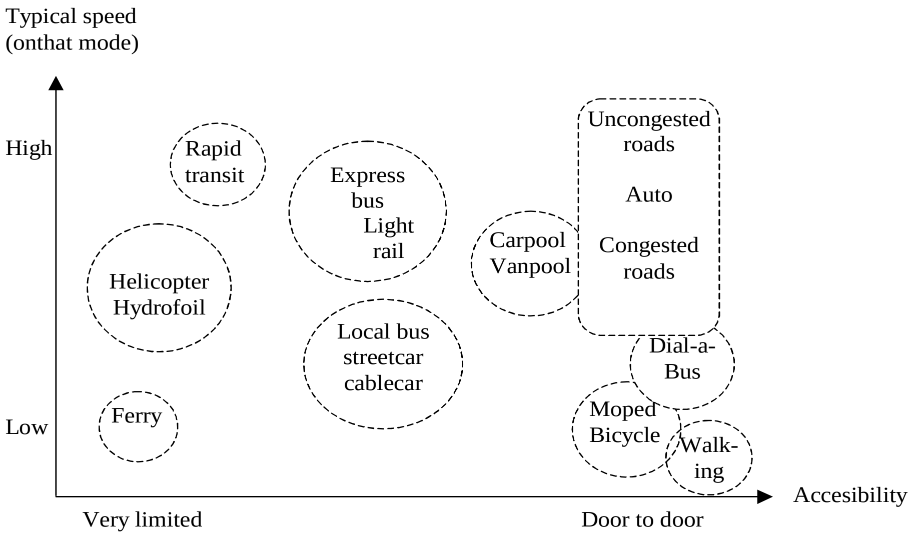


Figure 2.1 Characteristic of several kinds of passenger transportation modals

Source: Meyer & Miller

Table 2.2 shows the comparison of transportation modes in term of accessibility profiles. There are four main different accessibility profiles for different modes such as speed, user cost, user requirements and facilities [1]. In other words, different modes have different accessibility profiles. Looking into public transit, intercity bus and rail modes, it is clear that both have medium user cost, minimal user requirement and the same kind of facilities; roads and rail. Intercity bus and rail have a high speed in service while public transit is usually operated with medium speed. Those are very different with private automobile mode which has high speed, high user cost, license required and roadways for its facilities.

Table 2.2 Comparison of transportation modes

Mode	Speed	User cost	User requirements	Facilities
1. Walking	low	Low	Physical ability	Walkways
2. Cycling	Medium	Low	Physical ability	Paths/roads
3. Public Transit	Medium	Medium	Minimal	Roads/Rails
4. Intercity Bus and Rail	High	Medium	Minimal	Roads/Rails
5. Commercial Air Service	Very high	High	Minimal	Airports
6. Taxi	High	High	Minimal	Roadways
7. Private Automobile	High	High	License	Roadways
8. Ridesharing	Moderate	Low	Minimal	Roadways
9. Car Sharing	High	High	License	Roadways
10. Telecommunications	NA	Varies	Equipment	Equipment
11. Delivery Services	NA	Medium	Availability	Roadways

Source: “Transport Diversity,” VTPI [2]

Accessibility is described as the ability to reach desired goods, services, activities and destinations. Other terms of accessibility are convenience and opportunities. In transportation context, walking, cycling, ridesharing and public transit provide access to jobs, services and other activities. There are two kinds of transportation functions or goals, accessibility and movement.

According to Victoria Transport Policy Institute [1] there are four general factors affecting physical accessibility as follows:

1. Mobility as physical movement includes walking, cycling, public transit, ridesharing, taxi, automobiles, trucks and other modes.
2. Mobility substitutes such as telecommunications and delivery services affect the accessibility to some types of goods and activities which involve information.
3. Transportation system connectivity refers to the links directness and the density of connections in path or road network.
4. Land use as the geographic distribution of activities and destinations. The dispersion of destination increases the amount of mobility to access goods, services and activities, reducing accessibility.

People often evaluate accessibility with the generalized costs in terms of time, money, discomfort and risk to reach their activities. Most people expect to spend less travel time and less in financial costs on travel to reach their activities. Of course, minimum travel costs vary depending on personal preferences and conditions, but these are reasonable averages. Travel time tends to be the dominant component of accessibility where the marginal cost of travel is relatively low (for example, for automobile owners). In addition, convenience is the ease that they want. For example, a shop that is relatively accessible to consumers is called a convenience store and a home near common destinations is said to have a convenient location.

Accessibility varies based on the location, time and person. The degree of accessibility can affect the types of business, property values and economic development that occur in an area such as where you go, what you do, whom you know, your household costs and your opportunities for education, employment and recreation.

There are different perspectives regarding the accessibility such as from the perspective of a particular location, a particular group, or a particular activity. A particular location may be accessible by automobile but not by walking and transit. Therefore, non-drivers are difficult to reach the location. A particular group may have difficulty to access transport facilities such as people with physical disabilities. A particular type of activity such as commercial activity may also have different accessibility for automobile or large trucks.

2.1.1 Accessibility, Movement and Mobility

Accessibility to bus system is how easy people can reach and use bus service. There is an easy way to think of the accessibility. A concept of relationship is shown as follows,

$$mobility = accessibility + movement \tag{2.1}$$

This concept describes that movement and accessibility are in some way mutually exclusive. If accessibility increases, it is likely that movement would reduce and vice versa. Accessibility could be improved by reducing the distance between bus stops.

Thus, the distance that is necessary to walk to the bus stop is reduced. However, this would tend to reduce the commercial speed of buses and thus work against the movement-enhancing objective [3].

2.1.2 Accessible Journey Chain

According to Frye [4] as cited by [3], a public transportation journey is a set of linked elements which have to be accessible for the whole journey and is called the “accessible journey chain. Figure 2.2 presents the accessible journey chain and shows that a journey is possible if any element of the chain is accessible. This figure illustrates a concept of a journey involving travel on a bus. Therefore, the importance of accessibility of every link in transportation chain includes:

1. the accessibility to reach bus stop from the origin.
2. the possibility to design accessible boarding for either bus stop or the bus
3. the accessible bus must be designed to accommodate the needs of users
4. the bus station and bus stop are designed to provide acceptable interface for alighting passengers to achieve the destination
5. to reach destination, the walk from the last bus stop to destination is provided
6. the potential passenger should be able to find out the service exists and how to use it by means of an accessible information system.

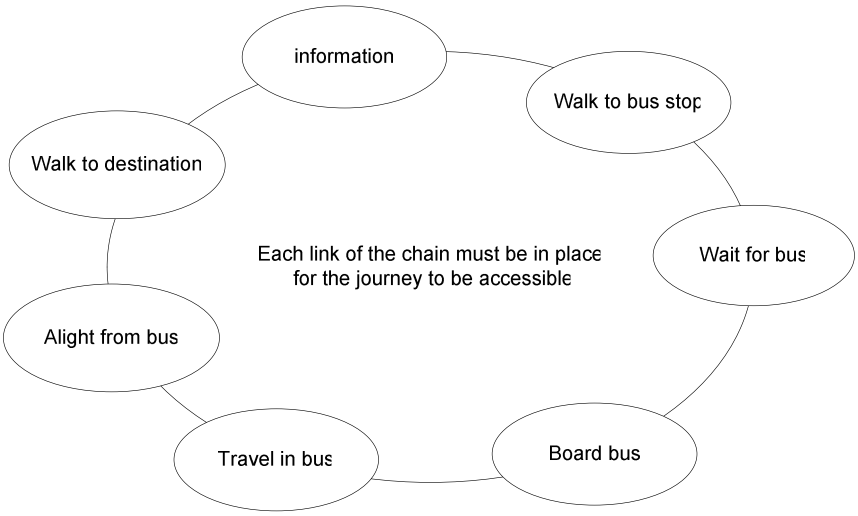


Figure 2.2 The accessible journey chain

Source: Accessibility and the Bus System: From Concepts to Practice, [3]

2.2 Public Transportation System

According to Papacostas and Prevendouros [5] a public transportation system is a transportation system which is available to the general public to use. The system does not concern about who owns it, operates it or who controls it. However, the system concerns its availability to public. It is the responsibility of the designers of a public transportation system to ensure that it is accessible. Public transportation system should be designed so everyone should be able to use it without the need for a private car.

The requirement of public transportation design is to ensure that the accessible journey chain is maintained. The capacity and accessibility are the objectives thus passengers can actually reach and use the system. Systems must be designed so that they provide accessibility throughout the chain even where different owners and operators are responsible for different parts of the chain. Although there are various owners, operators and their technologies, the system should be transparent to user to make a journey [3].

Trains and buses are usually considered to be public transportation, but taxis, specialized services, ambulances, footways and other pedestrian infrastructure are also public transportation system. The accessible journey chain includes phases such as the walk to and from bus stop and provision of information. As each of these must be accessible in order for the chain to be completed, they must be included in the public transportation system. For fair society in which people can reach and use the activities, the whole public transportation system should be fully accessible.

In the whole transportation system, it is generally noted that there are two term of transportation modes in passenger transportation such as private and public transportation [3, 5]. Public transportation is becoming important issues because of their contribution to facilitate people mobility instead of using private car. Research on public transportation system and all aspects surrounding public transportation planning and operations is currently interesting for international community of researchers, practitioners, vendors, academia, industry, government and also users.

Advanced public transportation system has been contributed by development of technology in telecommunication and computation, for example, computer-aided scheduling system, automated vehicle location, automated passengers counting, etc. Many other significant scopes of public transportation have been raised in many international community forums as follows [3]:

a. Public transportation network and route planning and design,
b. Timetables planning and generation,
c. Vehicles scheduling (bus, train, tram, ferry, airplane, etc.),
d. Driver and crew scheduling,
e. Operations monitoring, control and management such as real-time control and re-scheduling,
f. Information management,
g. Passengers information, trip planning and route guidance,
h. Public transportation regulations and competition,
i. Financial sustainability,
j. Public-private partnership,
k. Practical experience with scheduling and planning methods,
l. Other areas related to passenger transport (large-scale optimization, etc.) such as taxi services and railway planning and operations.

2.2.1 Role of Public Transportation

The role of public transportation includes many aspects in economic development and quality of life in communities worldwide. Among the vital contribution of public transportation are the aspects of accessibility, health and happiness, economic growth, education and job training, as mentioned in [6]. Therefore, the question is, why and how are the aspects above vital to public transportation service?

Moreover, as stated in [6], public transportation provides equal opportunities for all people to access a place and around regional destinations regardless of age, ability, or income. Furthermore, as mentioned in [6], in the aspect of health and happiness, public transportation will improve the quality of life for all residents in coverage area by connecting people to some health cares (doctors, hospital and pharmacies), the number of social activities and organizations (senior centers, service organizations, etc.) and some places of worship (mosque, church, temple, etc.), family, friends and the entire area. In relation with economic growth, public transportation will promote local economy by connecting residents, visitors and consumers to places such as shopping areas (grocery stores, gift shops, clothing stores, etc.) and entertainment and recreation areas (movies, restaurants, sporting events, etc.). Beside that, public transportation also improves educational opportunities and our workforce by connecting students and workers to educational activities (public and private schools, libraries, etc.), employment (manufacturing, retail, service industry, etc.), job training and welfare work and other social service programs. In environmental aspect, the other roles of public transportation were discussed on conserving energy and preserving the environment [7], emergency management [8], reducing green house gas emissions and improving energy efficiency [9].

2.2.2 Public Transportation Performance

The usual way to view public transportation is as a set of modes, gradually increasing in capacity, speed, comfort and cost, from the smallest and slowest component such as a taxi, to the largest, fastest element such as a high-speed train [3]. This concept, illustrated graphically in Figure 2.3, is generally used to determine if a railway, light rail, tram or bus system should be constructed in a particular situation. The aim of most public transportation system is to convey large number of people as quickly as possible, usually into or around a city centre. The point where the largest volume of passengers travels (the *maximum load* point) is the main constraint on the system, as this determines the maximum number of passengers that the system can carry.

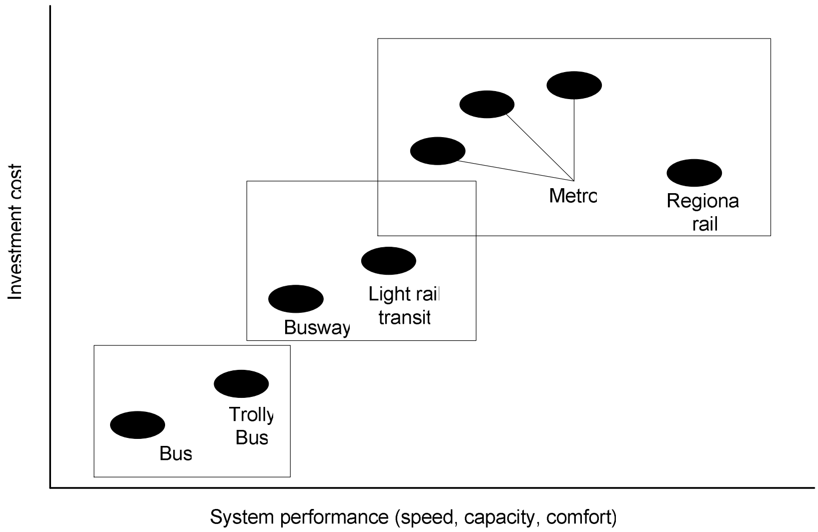


Figure 2.3 The system performance of different types of public transportation
Source: Accessibility and the Bus System: From Concepts to Practice [10] and Urban Transit: Operations, Planning and Economics [3]

2.2.3 Strategic Issues in Transportation Policy

Generally, in transportation planning in many countries, there are important policies such as maintenance, access to development, accident reduction, improved use of network and public transportation restraint environment. Roe [11] stated that promotion of efficient public transportation operation will support the transport policies such as (a) to ensure that roads and other facilities are maintained in a safe and serviceable condition, (b) to continue the strategic highway network development, (c) to increase the capacity of transport facilities both public and private, (d) to give priority to public transportation, (e) to restrain the use of private cars during peak period to avoid congestion.

2.3 Transit System Service

Many kind of transit system services have been developed around the world ranging from traditional operation system to high technological operation system in both rural and urban areas. American Public Transportation Association (APTA) reported the mass transit ridership increase in 1999 [12]. Table 2.3 below shows how rapid is the ridership increase. By comparing the number of demand (ridership) each public transportation mode in 1999, total ridership of bus is the highest, followed by heavy rail (subway system). The rate of increase is 3.84% for bus and 6.47% for heavy rail.

Table 2.3 The increase of the mass transit ridership in America

Mode	1999 ridership	Increase
1. Heavy rail (subway system)	2,686,000,000	6.47%
2. Trolley bus	126,500,000	6.14%
3. Demand response (elderly, disabled)	107,800,000	4.72%
4. Bus	5,360,400,000	3.84%
5. Commuter rail	393,700,000	3.76%
6. Light rail and other	383,500,000	0.91%

Source: Transportation Engineering, [12]

A kind of transit system service which is better managed with high technology, is called bus rapid transit (BRT). Diaz *et al* [13] stated that major elements of BRT include running way, stations, vehicles, fare collection, intelligent transportation system, service and operating plan. The service and operating plans of BRT have two important aspects such as the role and the characteristic of service and operating.

The characteristics of service and operations planning give several options as follows: route length, route structure, span of service options, frequency of service, station spacing and methods of schedule control. The service and operations plan elements can affect the system performance and system benefits. Below are brief aspects of BRT system such as elements, performances and system benefits.

1. BRT elements generally cover running ways, stations, vehicles, fare collection, intelligent transportation system (ITS) and service and operating plans.
2. BRT performance are including:
   i. Travel time: running time, station dwelling time, waiting time and transferring time
   ii. Reliability: running time, station dwelling time and service reliability
   iii. Identity and image: brand identity and contextual design
   iv. Safety and security
   v. Capacity: person capacity
3. The BRT system benefits include several aspects such as higher ridership, capital cost effectiveness, operating cost efficiency, transit-supportive land development and environmental quality.

2.3.1 Bus Service system

Bus service system is commonly chosen as the type of public transportation offered on the roads [3]. Although not all form of road-based public transportation might involve busses, bus system is the main focus of research and discussion. Bus system becomes the research focus by many researchers because:

1. Bus service incorporates all aspect of the accessible journey chain,
2. It involves design of vehicles, infrastructure and the interface between them,
3. It highlights conflicts and opportunities between public and private sectors,
4. It is more common than any other public transportation modes,
5. Its operational characteristics enable us to think in more practical terms about implementation,
6. It is easier to consider its integrated system of transportation modes (for example, it is more difficult to consider only a rail-based system as a single service).

2.3.2 Stakeholders Involved in Bus System Operation

In many countries, there are few stakeholders in relation with bus system operation such as users, operator or bus companies, regulator and society. They have are involved in bus system planning, operation and management whether in a direct or indirect way. In society, people who are not included as users are also an element which is not directly related to bus service operation. In general viewpoint, many activities are generated intensively by the established bus service operation such as economic, tourism, education and many other informal sectors. The brief explanation of the relation among each stakeholder is stated below.

a. Users

Users of bus service have a number of specific criteria and objectives to use bus service such as travel time and affordable fare. As commonly known, more people have started using motorcycles after petrol prices were increased. It was reflected in the higher number of new motorcycles registered, while the registration of new cars had declined. Therefore, the increase of motorcycle is likely could be related to the increase of petrol price. Meanwhile, more people also used public transportation as this could be indicated by comparing the increasing number of passengers before and after petrol price hike. This fact could describe that users are very interested in the bus service operation.

b. <u>Operator</u>

Operator of bus contributed to serve people mobility by operating the fleet of busses at a bus route determined by government (regulator) with applicable fare or ticket. Operators have to provide service during hour of service and they must undertake planning, designing, operating and management to ensure the users are enjoying the reliable and affordable bus service. Shortly, a set of quality of bus service has to be maintained by all stakeholders involved in order to achieve high performance of public transportation system in general.

To understand the contribution of bus operator in providing bus service, there is a bus operator's experience which is related to the case study in this research. The operator is Perak Roadways Sdn. Bhd. As mentioned by Jamaludin [14] and cited by Anderson [15], in 1950, there was a transportation business company in Perak, Malaysia, named Gajah Transport, to cater the increasing demand along the Tanjung Tualang-Sungai Durian route in Batu Gajah. Several years later, in 1954, the company changed its name to Perak Roadways Sdn. Bhd. and extending its service to Malim Nawar and Kampung Gajah. In 1968, the company was given another two routes; Ipoh-Lumut and Ipoh-Gerik. In 2004, with 60 staff, the company had branch offices in Medan Gopeng, Lumut, Grik, Shah Alam, Kota Baru in Kelantan and Betong in Thailand.

As mentioned by Anderson [15] it was cited that since a company providing a public service (bus transport) and the service had to run, it had to go out and do whatever was necessary. This shows how important a bus transport service is to be provided for public or demand. Additionally, there was recognition of Perak Roadways 50 years service to the community as being expressed by New Sunday Times on 17 October 2004 [14].

c. <u>Government (regulator)</u>

Government functions to arrange a set of policy and a rule to regulate, monitor, evaluate and improve the whole public transportation system. Trajectory, vehicle license and ticketing are among many important aspects that government must regulate. A well managed public transportation system can ensure that all people regardless age, income and location can access the service with the rate of fare as affordable as possible. Below is an example of scheduling and ticketing at Perak Roadways Sdn. Bhd., an operator which operates bus service on Ipoh-Lumut highway corridor, in Perak, Malaysia [16]. Table 2.4 shows the ticket fares during 2007. The information on the ticket fares and the schedule in Ipoh-Lumut in February and March 2009 are in Table 2.4. The schedule of bus service is in Table 2.5.

Table 2.4 The ticket fares during 2007 and 2009

Destination	2007		2009*	
	Adult	Child	Adult	Child
1. Lumut	6.50	3.00	8.40	3.80
2. Sitiawan	4.60	1.80	6.00	2.30
3. Ayer Tawar	3.40	1.70	4.40	2.20
4. Bota	3.10	1.50	4.00	2.00
5. Lumut (two way)	10.10	-	13.00	-

Note: * Survey on February – March 2009

Source: Perak Roadways Sdn. Bhd. [16]

Table 2.5 Operation schedule of bus service

Morning	Mid-day	Afternoon	Evening
Monday to Thursday			
6.50 AM	10.00 AM	3.00 PM	6.00 PM
7.30 AM	11.00 AM	4.00 PM	7.00 PM
8.00 AM	12.00 PM	5.00 PM	
8.30 AM	1.00 PM		
9.00 AM	1.30 PM		
	2.00 PM		
Friday, Saturday and Sunday (additional schedule)			
9.30 AM	2.30 PM	5.30 PM	

Source: Perak Roadways Sdn. Bhd. [16]

2.4 Bus Service Characteristics and Performance

To analyze the characteristics of bus services, the main data of bus operation were collected such as travel time, headway and load factor [17, 18]. In general, bus service characteristics consist of vehicle capacity (seats per bus), route distance (kilometer), route or trip time, operating speed (km per hour), headway (minute per bus), frequency (bus per hour) and number of vehicle (bus).

The study on bus service performance was done to deal with three performance concepts such as resource input, service output and service consumption [19]. Those characteristics covered resource-efficiency, resource-effectiveness and service-effectiveness. The other aspect related to bus service characteristics is bus users. Taniguchi et al. [20] studied on bus user characteristics comprising the sex, age, income, frequency usage, favorite serves, sharing users group, criteria of choosing bus service and motivation.

Additionally, according to Banks [18] a number of performance indicators are considered in the reviews of public transportation operation. Those include:

1. Total ridership for the route,
2. Average demand passed the maximum point,
3. Overloading, measured in term of the average number of standees or number or percent of trips exceeding a maximum load standard,
4. Revenue collected on the route,
5. Estimated cost of operating the route,
6. Fare box recovery ratio (ratio of fares to cost),
7. On-time performance, usually measured in terms of the fraction of the trips that are late by more than a specified amount of time,
8. Public input intake form of complaints, suggestions, etc.

These performance indicators may be evaluated individually or incorporated into some sort of overall performance indexes. Where deficiencies are noted, consideration will be given to corrective action including rerouting, rescheduling, special marketing effort, modified dispatching polices, or even elimination of service.

2.4.1 Standard of Bus Service Performance

In practice, there are some standards for evaluating viability of bus operation. World Bank standard can be used to evaluate the performance of urban public transportation system (Table 2.6). It should be noted here that the World Bank standard applies particularly to city buses, which usually have a low headway and a high service frequency. The World Bank standard may not be fully applied to every country depending on the operating costs and tariff. However, the World Bank standard could be used as a general guidance to judge viability of the bus operation.

The results of a study are able to be compared to the values of parameters in World Bank standard. As shown in Table 2.7, the standard was used to evaluate the service performance such as headway, travel distance per bus per day, number of passengers per bus per day, load factor and availability [17, 21].

Table 2.8 shows that the other standard adapted by Vuchic (1981) was also used for assessing the regular bus (comparison of technical, operational and system characteristics) [21, 22]. As published by Transportation Research Board [23], the Transit Capacity and Quality of Service Manual (TCQSM 2003), are also used to evaluate the service frequency, regularity and level of service.

Table 2.6 World Bank Standard for bus service performance

No.	Criteria	Parameter	Standard
1.	Rate of operated-available vehicle ratio	Ratio between number of operating vehicle and number of planned vehicle or available (%)	80-90
2.	Utility of vehicle	Average of traveled distance every day (km/day)	210-260
3.	Number of passenger	Number of passenger loaded each bus per day (persons/bus/day)	440-525
4.	Productivity of management	- number of administrative staff / bus	0.3-0.4
		- number of workshop staff / bus	0.5-1.5
		- number of total staff / bus	3-8
5.	Rate of accident	Number of accident each 100.000 km traveled distance (accident/100.000 bus-km)	1.5-3
6.	Rate of upholding or preservation	The percentage of number of bus in preservation to the total bus operated (%)	8-10
7.	Fuel consumption	The volume of fuel consumed each bus per 100 km of travel distance (liter/bus-100 km)	25-50
8.	Operating ratio	Ratio between revenue and operating cost (depreciation included)	1.05-1.08
9.	Load factor	Ratio between number of passenger and capacity of bus (number of seats) in a period of time (%)	70
10.	Number of transferred passenger	- no transfers/transit	> 50%
		- 2 transfers (twice)	< 10%

Source: World Bank Technical Paper Number 68: Urban Transport Series, [24]

Table 2.7 World Bank Standard for bus performance

No	Parameters (units)	Standard
1.	Headway (minutes)	1-12
2.	Travel distance (km/bus/day)	230-260
3.	Number of passengers (pass/bus/day)	440-525
4.	Load factor (%)	70
5.	Availability (%)	80-90

Source: Arintono *et al*. and Sulistyorini [17, 21]

Table 2.8 Performance and characteristics of regular bus (RB)

No	Parameters	Units	Standard
1.	Vehicle capacity	seats/bus	40-120
2.	Frequency	bus/h	60-180
3.	Passenger capacity of route	pass/h	2400-8000
4.	Operating speed	km/h	15-25
5.	Lane width (one-way)	m	3.00-3.65
6.	Vehicle control	-	man/vis
7.	Reliability	-	low-med
8.	Safety	-	med
9.	Station spacing	m	200-500

Note: man : manual, vis : visual, med : medium

Source: Vuchic (1981) - Adapted for regular bus [22]

2.4.2 Measuring Quality of Service by Using TCQSM Method

Transit Capacity and Quality of Service Manual (TCQSM) manual is available to evaluate transit capacity and quality of service (QOS). The transit performance measures are reflected by the quality of service of the system. Quantitative and qualitative factors are used to evaluate particular aspects of transit service. A numeric performance measure converted into an A to F grade. It helps to explain on how good or bad a service is from the passenger's point of view. LOS A represents best performance. Meanwhile, LOS F represents an undesirable condition from passenger's perspective or viewpoint. This LOS concept is introduced by HCM in 1965 and adopted by TCQSM. There is a difference between QOS and LOS. QOS is the overall measured or perceived performance of transit service from the passenger's point of view. Meanwhile, LOS is a way to measure QOS. There are six ranges of values for a measure, grades from A to F. For detail, the measurement is shown in Table 2.9 to Table 2.17.

Table 2.9 Fixed-route QOS framework

	Service measures		
	Transit stops	Route segments/corridors	System
Availability	Frequency	Hours of service	Service coverage
Comfort & convenience	Passenger load	Reliability - on-time performance - headway adherance	Transit-auto travel time

Note: Frequency is the number of transit vehicles serving the same destination in an hour (vehicles/hour). Headway is the inverse of frequency, meaning the interval between transit vehicles serving the same destination (minute).

Source: Transit Capacity and Quality of Service Manual-2nd Edition, [23]

Table 2.10 Demand-responsive QOS framework

	Service measures		
Availability	Response time	Service span	-
Comfort & convenience	On-time performance	Trips not served	DRT-auto travel time

Note: DRT = demand responsive transit

Source: Transit Capacity and Quality of Service Manual-2nd Edition, [23]

Table 2.11 Headway LOS

LOS	Average. headway (min)	Veh/h	Comments
A	<10	>6	Passengers do not need schedules
B	10-14	5-6	Frequent service, passengers consult schedules
C	15-20	3-4	Maximum desirable time to wait if bus/train missed
D	21-30	2	Service unattractive to choice riders
E	31-60	1	Service available during the hour
F	>60	<1	Service unattractive to all riders

Source: Transit Capacity and Quality of Service Manual-2nd Edition, [23]

Table 2.12 Hours of Service LOS

LOS	Hours of service	Comments
A	19-24	Night or “owl” service provided
B	17-18	Late evening service provided
C	14-16	Early evening service provided
D	12-13	Daytime service provided
E	4-11	Peak hour service only or limited midday service
F	0-3	Very limited or no service

Source: Transit Capacity and Quality of Service Manual-2nd Edition, [23]

Table 2.13 Service coverage LOS

LOS	% TSA covered*	Comments
A	90.0-100.0%	virtually all major origins & destinations served
B	80.0-89.9%	most major origins & destinations served
C	70.0-79.9%	about ¾ of higher-density areas served
D	60.0-69.9%	about two-thirds of higher-density areas served
E	50.0-59.9%	at least ½ of the higher-density areas served
F	<50.0%	less than ½ of higher-density areas served

Note: * TSA is abbreviation of transit-supportive area.

Source: Transit Capacity and Quality of Service Manual-2nd Edition, [23]

Table 2.14 Passenger load LOS

LOS	Load factor	Standing passenger area		Comments
		(ft^2/p)	(m^2/p)	
A	0.00-0.50	>10.8*	>1.00*	No passenger need sit next to another
B	0.51-0.75	8.2-10.8*	0.76-1.00*	Passengers can choose where to sit
C	0.76-1.00	5.5-8.1*	0.51-0.75*	All passengers can sit
D	1.01-1.25**	3.9-5.4	0.36-0.50	Comfortable standee load for design
E	1.26-1.50**	2.2-3.8	0.20-0.35	Maximum schedule load
F	>1.50**	<2.2	<0.20	Crush load

Note: * used for vehicles designed to have most passengers standing
** approximate value for comparison, for vehicles designed to have most passengers seated. LOS is based on area.

Source: Transit Capacity and Quality of Service Manual-2nd Edition, [23]

Table 2.15 On-time performance LOS (as a parameter of reliability)

LOS	On-time performance	Comments*
A	95.0-100.0%	1 late transit vehicle every 2 weeks (no transfer)
B	90.0-94.9%	1 late transit vehicle every weeks (no transfer)
C	85.0-89.9%	3 late transit vehicle every 2 weeks (no transfer)
D	80.0-84.9%	2 late transit vehicle every weeks (no transfer)
E	75.0-79.9%	1 late transit vehicle every day (with a transfer)
F	<75.0%	1 late transit vehicle at least daily (with a transfer)

Note: Applies to routes with a published timetable, particularly to those with headways longer than 10 minutes. “On-time” is 0 to 5 minutes late and can be applied to either arrivals or departures, as appropriate for the situation being measured. Early departures are considered on-time only in locations where no passengers would typically board (e.g., toward the end of a route). * Individual’s perspective, based on 5 round trips per week.

Source: Transit Capacity and Quality of Service Manual-2nd Edition, [23]

Table 2.16 Headway adherence LOS

LOS	C_{vh}	P(|hi-h| > 0.5 h)	Comments
A	0.00-0.21	≤2%	Service provided like clockwork
B	0.22-0.30	≤10%	Vehicles slightly off headway
C	0.31-0.39	≤20%	Vehicles often off headway
D	0.40-0.52	≤33%	Irregular headways, with some bunching
E	0.53-0.74	≤50%	Frequent bunching
F	≥0.75	>50%	Most vehicles bunched

Note: * headway adherence is as a parameter of reliability – the ‘bunching’ effect

Source: Transit Capacity and Quality of Service Manual-2nd Edition, [23]

Table 2.17 Transit-auto travel time LOS

LOS	Travel time difference (min)	Comments
A	≤0	Faster by transit than by automobile
B	1-15	About as fast by transit as by automobile
C	16-30	Tolerable for choice riders
D	31-45	Round-trip at least an hour longer by transit
E	46-60	Tedious for all riders; may be best possible in small cities
F	>60	Unacceptable to most riders

Source: Transit Capacity and Quality of Service Manual-2nd Edition, [23]

2.4.3 Travel Time, Route Distance and Operating Speed

Three basic elements of bus running are considered such as travel time, route distance and operating speed. In planning, operation and management of bus service, the operating speed is an important factor, which is determined by travel time and route distance. The operating speed of bus service could not be discussed apart from design speed of a road. As bus service is operated in mixed traffic, for example, the operating speed will be different for each road classification (road type). Each type of road has a typical design speed, both rural and urban area.

Speed is a primary factor in all modes of transportation and is an important factor in the geometric design of roads [25]. The speed of vehicles on a road depends upon general conditions such as the physical characteristics of the highway, the weather, the presence of other vehicles and the legal speed limitations. The speeds are selected to meet the needs of the road to fulfill its function. The road for providing long distance travel is designed with a higher speed while those providing short travel distance are given a lower design speed.

Operating speed is the highest overall speed at which a driver can travel on a given road under favorable weather conditions and under prevailing traffic conditions without at any time exceeding the design speed on a section by section basis.

Design speed is the maximum safe speed that can be maintained over a specified section of the road when conditions are so favorable that the design features of the road governs. The assumed design speed is a logical one with respect to the topography, the adjacent land use and type of road. A practicable design speed is chosen to maintain the desired degree of safety, mobility and efficiency.

Classification of highway is shown in the following table (See Table 2.18). For example, a bus system which is operated on the R5 road with a design speed of 100 km/hour will have limitation difference within U5 in urban area.

Table 2.18 Design speed (for rural and urban road)

Rural	(km/hour)			Urban	(km/hour)		
Design	Terrain			Design	Area Type		
Standard	F	R	Standard	Standard	I	II	III
R6	120	100	U6	U6	100	80	60
R5	100	80	U5	U5	80	60	50
R4	90	70	U4	U4	70	60	50
R3	70	60	U3	U3	60	50	40
R2	60	50	U2	U2	50	40	30
R1	40	30	U1	U1	40	30	20
R1a	40	30	20	U1a	40	30	20

Note: Abbreviation: F = flat, R = rolling, M = mountainous
Type I – relatively free in road location with very little problems as regards land acquisition, affected buildings or other socially sensitive areas.
Type II – intermediate between I and III
Type III – Very restrictive in road location with problems as regards land acquisition, affected buildings and other sensitive areas

Source: A Guide on Geometric Design of Roads, JKR [25]

2.4.4 Highway Level of Service

Prior to the level of service for bus service system, the concept of level of service of highway is introduced. Level of service (LOS) is a simple concept as defined into a volume to capacity ratio (V/C ratio) for the purpose of design to determine the service volume of road. Table 2.19 gives the indication of levels of service used. Table 2.20 shows the relation between LOS and V/C ratio. The service volume is the maximum volume of traffic that a designed road would be able to serve without the degree of congestion falling below a pre-selected level as defined by the level of service which is the operating conditions (freedom to maneuver) at the time the traffic is at the design hour volume.

Capacity of highway is the ability of a roadway to accommodate traffic and is defined as maximum number of vehicles that can pass over a given section of a lane or a roadway during a given time period under prevailing roadway and traffic conditions. The capacity which is considered here is only applicable to uninterrupted flow or open roadway conditions. Capacity is also usually stated in terms of passenger car units (p.c.u). Passenger car unit is obtained by converting the various classes of vehicles by using conversion factors. Figure 2.4 gives a schematic concept of the relationship of level of service to operating speed and volume/capacity ratio [5, 25].

Table 2.19 The indication level of service

Level of Service	Remarks
A	Free flow with low volumes, densities and high speeds. Drivers can maintain their desired speeds with little or no delay.
B	Stable flow. Operating speeds beginning to be restricted somewhat by traffic conditions. Some slight delay.
C	Stable flow. Speeds and maneuverability are more closely controlled by higher volumes. Acceptable delay.
D	Approaching unstable flow. Tolerable operating speeds which are considerably affected by operating conditions. Tolerable delay.
E	Unstable flow. Yet lower operating speeds and perhaps stoppages of momentary duration. Volumes are at or near capacity congestion and intolerable delay.
F	Forced flow. Speeds and volume can drop to zero. Stoppages can occur for long periods. Queues of vehicles backing up from, a restriction downstream.

Source: Jabatan Kerja Raya (JKR), Malaysia [25]

Table 2.20 Level of service and V/C ratio

Rural			Urban		
Road category	Design level of service	V/C ratio	Road category	Design level of service	V/C ratio
Expressway	C	0.70-0.80	Expressway	C	0.70-0.80
Highway	C	0.70-0.80	Arterial	C	0.70-0.80
Primary road	D	0.80-0.90	Collector	D	0.80-0.90
Secondary road	D	0.80-0.90	Local street	E	0.90-1.00
Minor road	E	0.90-1.00			

Source: Jabatan Kerja Raya (JKR), Malaysia [25]

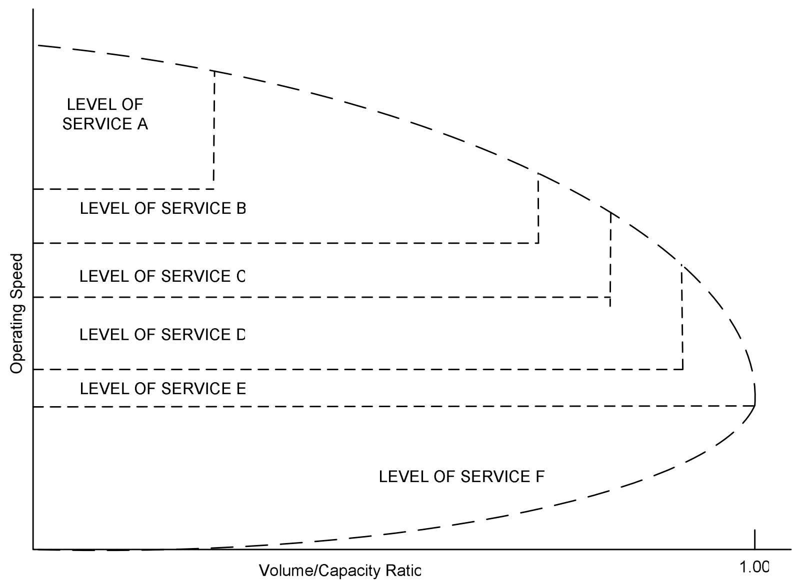


Figure 2.4 The relationship of LOS to operating speed and V/C ratio

Source: Jabatan Kerja Raya (JKR), Malaysia [25]

2.4.5 Ipoh-Lumut Corridor Bus Service

Key features of the future road network in Perak include the Ipoh-Lumut bypass (in upgrading process) and a proposed ring road around the Central Planning Area (CPA) [26]. In the future context of industrial development, Ipoh will become the administrative and commercial center rather than just an industrial hub. There is an industrial land around Ipoh. The sub-regional provision of industrial lands outside Ipoh are targeted to be developed as new growth centers are sited in Chemor, the Ipoh-Batu Gajah-Lumut corridor and the Simpang Pulai corridor. These sub-regional development will help the State meets its program for continued growth in industrialization thus providing employment opportunities [27].

The current bus system in the region has several problems such as limitation of facilities, the use of low quality buses, inconvenience of fleets, low passenger trips, long waiting time, etc. Waiting time of around 40 minutes is very common, which makes the system not attractive to passengers. Besides, in Ipoh buses only represents about 2% of the total vehicle flow [27, 28]. In other words, the modal split indicated that the general use of local bus services in Ipoh is relatively low and this is expected to decline further if no action is taken. The increase in travel demand in the area will continue to be catered by private car. This phenomenon will subject the roads or highway to greater burden because of the road space restriction. Some alternatives form of public transportation must be provided.

Ipoh-Lumut bus route is a link between Ipoh (center of city) and Lumut (attracting local and foreign tourists place). A divided 4-lane 2-way highway is the existing road in Ipoh-Lumut corridor at which bus service is available. However, the Highway Planning Unit indicated an overall traffic annual growth rate of 12%. The growth rate is significantly higher in the more industrialized areas of Perak such as Ipoh and Lumut. This certainly put a lot of pressure on the existing road network and will justify a capacity of existing bus service system. Therefore, the assessment on the operation, reliability and the whole quality of service of the current bus system is needed.

2.4.6 On-Time Performance and Service Regularity

a. <u>On-time performance</u>

It was assumed the accepted on-time interval is 0 to 5 minutes [29]. The on-time performance of 0 to 5 minutes after departure time is considered. However, the use of higher interval such as 0 to 10 and 0 to 15 minutes, are also applicable for rural bus service with long route distance. The ideal on-time performance is 100%, where higher percentage indicates better performance of bus service. On-time performance is affected by route, schedule, driver and operating characteristics [30]. On-time performance at main bus stations was better than at bus stops, due to the availability of layover/recovery time at main bus station.

b. <u>Service regularity</u>

The demand on public transportation is considerable affected by the public transportation service level. Public transportation service level is generally influenced by a number of factors such as accessibility, waiting time, journey time, reliability, punctuality, fare, information and level of service.

In viewpoint of users, the quality of bus service includes three aspects such as reliability, safety and comfort. The reliability of bus service is directly influenced by the regularity of service [31]. The regularity at bus station and all bus stops are calculated based on the departure and arrival time, respectively. The regularity value is measured in percentage of trips fall within interval of ±5 minutes, ±10 minutes, ±15 minutes and ±30 minutes of scheduled arrival or departure time. Regularity is measured based on the timetable. Regularity is calculated for typical patterns, for example daily, monthly, annually service, etc.

As one of those factors, the simple understanding of the needs of reliability of public transportation is about how reliable the bus is at the scheduled departure time during service hours. Reliability includes regularity and punctuality of bus operation. Regularity can be defined as the percentage of intervals between actual trips that are within the acceptable interval at a location or a station during the service. Regularity is addressed to users concern about how long they must wait from the time they arrive at the station until the depart time of the next bus [29]. High regularity means that bus users can ensure to get bus service as well as its scheduled. Other than that, punctuality is how high the time gap between the actual and scheduled arrival time is performed. Punctuality is related to headway adherence. Headway adherence, or evenness of interval, is the service reliability criterion that measures reliability much the way a customer would see it [32].

2.4.7 Punctuality Index and Expected Average Waiting Time

Punctuality indexes of a bus stop or a bus station for a bus route also indicate the reliability of bus service [33]. This index is indicating of the magnitude of time gap between actual arrival time and scheduled arrival time (headway adherence) [34]. The longer headway adherence, the lower punctuality index indicates. By referring to standard, the reliability of bus service based on the headway adherence can be used to determine the level of service (LOS). Punctuality indexes of a bus stop for a bus route, P_I, is index indicating the magnitude of time gap between actual arrival time and scheduled arrival time (adherence) [35].

$$P_I = \frac{S_I^2}{h_t^2} \tag{2.2}$$

$$S_I^2 = \frac{1}{I}\sum_{i=1}^{I}(t_i - \tau_i)^2 \tag{2.3}$$

Where, h_t : Scheduled headways; I : Number of operations; t_i : Actual arrival time of i-th bus; τ_i : Scheduled arrival time of i-th bus; S_I : Standard deviation; P_I : Punctuality index

Headway adherence is time gap between actual arrival time and scheduled arrival time. By referring to TCQSM 2003 [23], the coefficient of variation of headway is calculated as follows:

$$\mathrm{C}_{vh} = \frac{\text{standard deviation of headway deviations}}{\text{mean scheduled headway}} \tag{2.4}$$

where: C_{vh} = coefficient of variation of headways

In TCQSM 2003, headway adherence is based on the coefficient of variation of headways, which can be related to the probability $P_I(|h_i - h| > 0.5h)$ that a given transit vehicle's headway will be off-headway by more than one-half the scheduled headway and the level of service (LOS) is divided according to the linear increase of the probability $P_I\left(\left|h_i - h\right| > 0.5h\right)$. Headway deviations are measured as the actual headway minus scheduled headway. To classify the level of service of bus operation, it is necessary to refer to Table 2.21.

Table 2.21 Fixed-route headway adherence LOS

LOS	C_{vh}	$P_I(\|h_i-h\|>0.5h)$	Factor $(1+P_I)$*	Comments
A	0.00-0.21	1%	<1.04	Service provided like clockwork
B	0.22-0.30	10%	1.05-1.09	Vehicles slightly off headway
C	0.31-0.39	20%	1.10-1.15	Vehicles often off headway
D	0.40-0.52	33%	1.16-1.27	Irregular headways, with some bunching
E	0.53-0.74	50%	1.28-1.55	Frequent bunching
F	>0.75	>50%	>1.55	Most vehicles bunched

Note: * The value of multiplier factor in calculating the expected average waiting time.

Source: TCRP Report 100: TCQSM 2003 [23]

When passengers randomly arrive at the bus stop, the expected average waiting time of passengers is a function of the punctuality index. The punctuality index is a determining factor in calculating the expected average waiting time of passengers and is a statistically representative index to indicate the variation against the average. According to Chang & Hsu [36], Osuna & Newell [37], as recited by Park & Kho [34] the passenger's expected waiting time is as follows:

$$E(W) = \frac{\bar{h}}{2}\left[1 + \left(\frac{S}{\bar{h}}\right)^2\right] = \frac{\bar{h}}{2}\left(1 + P_I\right) \qquad (2.5)$$

$$P_I = \left(\frac{S}{\bar{h}}\right)^2 = (\mathrm{C}_{vh})^2 \qquad (2.6)$$

Where, S : standard deviation of headway deviations

$\bar{h}$: mean scheduled headway

P_I : index to represent punctuality

If all vehicles run at an even headway, passenger's expected waiting time becomes a minimum value i.e. half of the mean headway. Notice that the expression ($1+P_I$) in the right part of the equation (2.9) becomes a multiplier to the minimum expected waiting time, which increases as the standard deviation of headway deviations increases. The larger the P_I value is, the less regular the headway is (See Table 2.22) [35]. If all buses arrive at bus stop on time, the punctuality index P is zero and the minimum value of expected average waiting time of passengers is obtained. If the distribution of bus arrival times is random, therefore, the P_I will be a maximum, indicating the worst situation.

It is suggested for the convenience of passengers and people to converse the P_I into percentage value. So, generally passengers and people recognize that the punctuality is high if the buses arrive evenly (on-time). Then, punctuality index, P_I can be conversed into percentage value (ρ) as follows:

$$\rho = [\text{Percentage value of punctuality index } P_I] = (1 - P_I) \times 100 \tag{2.7}$$

Table 2.22 Punctuality index and expected average waiting time of passengers

Punctuality Index	Expected average waiting time of passengers		Arrival type
$P_I = 0$	$E\{W\} = \frac{1}{2}\bar{h}$	(Minimum waiting time)	All buses arrive on time
$P_I = 1$	$E\{W\} = \bar{h}$	(The worst case of practically)	Complete random arrival

Source: Kho, et al., Journal of the EASTS Vol. 6 [35]

2.5 Analysis of Improvement for Bus Service

The improvement of bus service system planning and operation is made by following the steps and by considering the aspects below. Among the important aspects in bus service planning and operation discussed in this section are determination of route, number of fleets, number of bus stop, bus priority, bus lane and the elasticity of bus service demand. The elasticity of bus service demand can be measured by using many factors such as ticket fare, fuel price, income and service frequency.

2.5.1 Route Determination

In the case of study to improve bus service, the bus route is determined. The aspects considered to choose the bus route are the center of activities in urban or rural area, functional hierarchy of city or area, the existing road network, the demand of public transportation and potential sectors development (for example, socio-economic).

2.5.2 Determination of Number of Fleets

The steps of determination of fleets number (See Figure 2.5) are as follows:

1. Time of circulation

$$CT_{a-b-a} = T_{a-b-a} \tag{2.8}$$

Where, $T_{a\text{-}b\text{-}a}$: length of route divided by operating speed

2. Load factor

Load factor is ratio between number of seats used by passengers and vehicle capacity available during bus traveling along the route. A formula is given,

$$LF = \frac{H \times P}{60 \times C} \tag{2.9}$$

Where, LF is load factor, $H = CT_{a-b-a} / K$ is headway in minute, P is number of passengers, C is capacity of vehicle or bus and K is number of vehicle or bus.

3. Headway

$$H = \frac{60.C.LF}{P} \tag{2.10}$$

Where, C is capacity of bus, LF is load factor and P is number of passengers at the point (maximum)

4. Number of fleets

$$K = \frac{CT}{H.Fv} \tag{2.11}$$

Where, CT is circulation time; H is headway; Fv is factor of vehicle availability (100%). To meet with LF_{max} = 1.0 then value of K must be rounded up

5. Load factor

$$LF = \frac{H.P}{60.C} = \frac{CT.P}{60.C.K} \tag{2.12}$$

Where, H is headway, K is number of fleets/vehicle, CT is time circulation, C is capacity of bus and P is number of passengers.

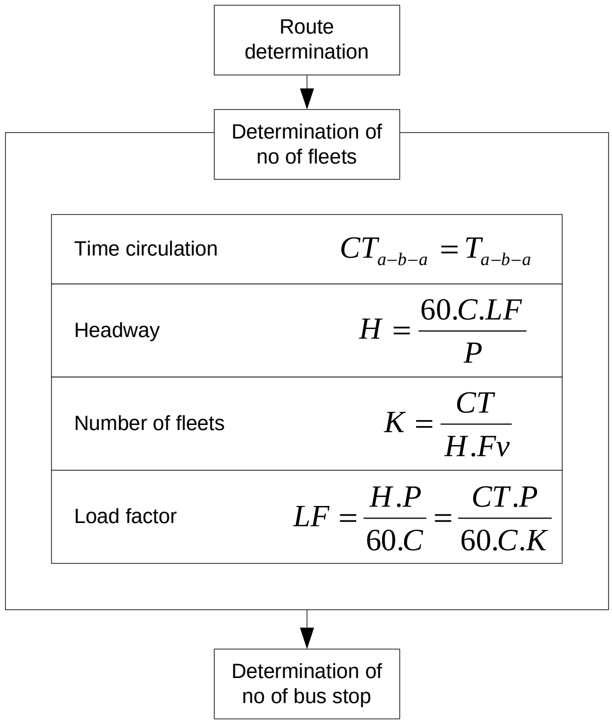


Figure 2.5 Improvement of bus service planning

2.5.3 Determination of Number of Bus Stops

Bus stop location planning includes the number of bus stop proposed and the distance between bus stops. Calculation of the number of bus stop is done by following the steps below. A number of factors considered to calculate the number of bus stop and distance of bus stop include the purpose of users' trip, distance traveled and type of area. The purpose of users' trip is categorized into trip within central business district (CBD), urban and semi urban. The maximum walking distance is in Table 2.23.

Table 2.23 The maximum walking distance

Location	Maximum walking distance (meter)
CBD	200
Urban	200
Semi urban	500

Source: Wigenrat, 1989

The distance traveled will be affecting the maximum walking distance. The longer the distance will be traveled by using public transportation, the longer people are willing to walk to bus stop or shelter, as shown in Table 2.24 below.

Table 2.24 Maximum walking distance and distance traveled

Distance traveled (m)	S max (m)
< 5.000	500
5.000 – 10,000	750
> 10,000	1000

Source: Wigenrat, 1989

The maximum walking distance is influenced by the type of areas (See Table 2.25 below). In the CBD, the maximum walking distance (400 m) for designing bus stop is considered shorter than that of urban (600 m) and semi urban (800 m).

Table 2.25 Maximum walking distance and type of area

Type of area	*S* maximum (meter)
CBD	400
Urban	600
Semi urban	800

Source: Wigenrat, 1989

Based on the maximum walking distance (d_w) then the distance of bus stop is calculated by the following formula:

$$S = 2.S_{\max} - 1/\beta \tag{2.13}$$

Where, S = distance between bus stop or shelter (meter)

S_{max} = maximum walking distance (meter)

β = density of public transportation route (m/m^2)

With

$$\beta = \frac{length\_of\_route}{service\_area} \tag{2.14}$$

According to type of areas and intensity of activities (density of activity), the higher the intensity of activities in certain area, the distance between bus stops or shelters will be shorter.

Table 2.26 General guidelines for determining the distance of shelter

No	Activities	Location	Type of bus stop / shelter	Distance between shelters (m)
1	Very high density commercial areas	CBD/urban	With safety cover	200-300
2	Dense combination of administration, education and commercial area	Urban	With safety cover	300-400
3	High level Residence area	Urban	No safety cover	300-400
4	Dense combination of residence, education and commercial area	Semi-urban	With safety cover	300-400
5	Medium combination of residence, farming and un occupied area	Semi-urban	No safety cover	500-1000

Source: Wigenrat, 1989

2.5.4 Bus Facility Improvement

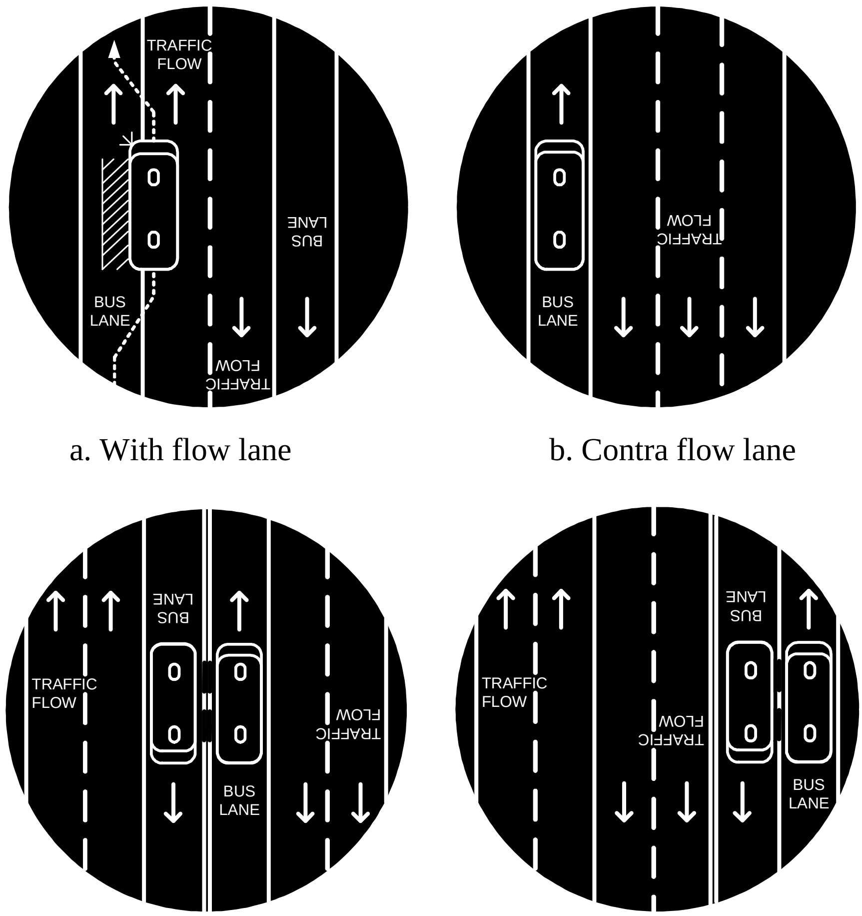
A number of alternative of bus system improvement include bus priority, bus lane, bus stop and bus parking and terminal. Bus priority is applied with some reasons such as when traffic jam is caused by private cars reaches its peak level and when cars parked on road trunk or the effect of right turn disturbs public transportation movements. Under these conditions, the service speed is reduced so much that more buses need to be operated to maintain adequate service frequency. When additional buses are not available, the service frequency decreases and the users will choose other modes of transport that will actually worsen the jam. When bus priority application succeeds, it brings a satisfactory level of public transportation service although traffic jam on other lanes may persist. Finally, this could attract users to use public transportation.

Bus lane and its use is defined as to give priority to buses by restricting other kinds of traffic sharing the same lane to enable buses to operate smoothly without any potential disturbances from other vehicles. Bus lane system needs a separate lane to improve public transportation facilities and services [38]. This is applied on busy streets only to avoid stuck in traffic jam.

As shown in Figure 2.6, there are several methods of bus lane application as follows [39]:

a. With flow lane; bus lane is made with flow (parallel with other traffic flow) and is placed on the left lane. It needs distinguished and understandable sign posts or a divider to help road users identify the lane.
b. Contra flow lane; bus lane is made contra flow (of opposite direction against other traffic flows) and is placed on the right lane. A contra flow lane has self-enforcing quality as buses are big and can be seen easily by users of other vehicles. Still, it needs clear signs or divider to avoid accident.
c. Axial lane; a two-way lane can be placed in the middle of a street and be given a physical divider to separate it from other traffic flows and a crossing facility at each stoppage.

d. Unilateral lane; a two-way (unilateral) bus lane is placed on one side of the street and is given a physical divider from other traffic flow and a crossing facility at each stoppage.



a. With flow lane

b. Contra flow lane

c. Axial lane

d. Unilateral lane

Figure 2.6 Diagram of bus lane application methods

Source: Roads and Traffic in Urban Areas, Hills (1987) [40]

Public transportation as the major transport service for middle to low class societies suffers from this situation as buses have to share the same lane with private cars which are growing bigger in number, resulting in lower public transportation service quality. The application of bus lane is, therefore, expected to improve public transportation service.

There is increasing flow from the condition before the application of bus lane. Bus travel time decreases while passenger car and motor bike travel time decreases [41]. Bus operating speed increases but passenger cars and motorbikes speed decrease. This measurement covers street capacity, travel time and speed at which parking prohibition on trunk roads is included.

2.6 Sensitivity of Bus Service Demand

This section discusses the analysis of bus service demand containing two parts. The first part is the analysis of bus service demand and estimation of trip distribution of bus passengers. In the next part, the concept of elasticity and sensitivity are also explained.

2.6.1 Bus Service Demand and Trip Distribution

1. Trip production and attraction

In transport demand study, zonal trip production or attraction is generally derived from the household based trip and socio-economic by zone [5, 22]. Trip production or attraction is measured in a person's trip. In terms of bus service ridership, for example, trip production or attraction is reflected by the number of passengers per day. Based on the trip generation or attraction, the unknown matrix of demand or ridership of bus service of each pair of zones is estimated by gravity model.

2. Trip distribution and gravity model

In the transport demand analysis, there are four phases generally known for demand modeling system such as trip generation, trip distribution, modal split and traffic assignment [5, 22, 42]. As in [42, 43], the simple understanding ways of the four phases are as follows:

a. trip generation which is the number of trip ends generated in each zone,
b. trip distribution is the zones the trips go to,
c. modal split is trips by private vehicle versus trips by public transit between each pair of zones. In other words, it is movements between only two zones and
d. traffic (network) assignment which is the routes the trips take between zones.

By considering on trip distribution, there are three main methods of conducting trip distribution such as intervening opportunities model, the Fratar model and the gravity model. In many applications of transportation planning in the world, the gravity model is frequently used.

As the gravity model is derived from Newton's law of gravity, in term of transportation planning, therefore, gravity model is the number of trips between two zones which is directly related to activities in two zones and inversely related to the separation between the zones as a function of the travel time, distance and travel cost. The gravity model predicts that the trip between two zones is: 1) directly proportional to the trip generations of each zone and 2) inversely proportional to a function of the spatial separation between these two zones [44, 45].

The gravity model is mathematically expressed as [5, 22, 46, 47]

$$T_{ij} = P_i \frac{A_j F_{ij} K_{ij}}{\sum_{j=1}^{n} A_j F_{ij} K_{ij}} \tag{2.15}$$

where $F_{ij} = f(t_{ij})$

and T_{ij} = number of trips produced in zone *i* and attracted to zone *j*,

P_i = total trip produced from zone *i*,

A_j = total trip attracted to zone *j*,

F_{ij} = friction factor for trip interchange *ij*,

K_{ij} = socioeconomic adjustment factor for interchange *ij* if necessary,

t_{ij} = travel time (or impedance) for interchange *ij*,

i = origin zone number, *i* = 1, 2, 3, …, n,

j = destination zone number, *j* = 1, 2, 3, …, n and

n = number of zones in the study area.

In the gravity model, the trips (P_i) produced in zone *i* will be distributed to zone *j* (T_{ij}) according to the relative attractiveness of each zone *j* ($A_j / \sum A_j$) and the relative accessibility of each zone *j* ($F(t_{ij}) / \sum F(t_{ij})$); this means that the trips between zone *i* and *j* equals to trips produced at zone i multiplied by the ratio of attractiveness and accessibility characteristics of zone *j* to attractiveness and accessibility characteristics of all zones in the study area. Therefore, zone *j* gets a portion of zone *i*'s trip productions according to its characteristics as compared to the characteristics of all other zones in the study area [22].

Schoon [42] states, for the manual application, K_{ij} has been discarded altogether due to the assumption $K_{ij} = 1$. The simply form of gravity model formula becomes:

$$T_{ij} = R_i A_j F_{ij} \tag{2.16}$$

where
$$R_i = \frac{P_i}{\sum_{j=1}^{n} A_j F_{ij}} \tag{2.17}$$

R_i = called the "production index" (a constant for each production zone i),

$A_j F_{ij}$ = the "attraction factor" for analysis area j *and*

$\sum_{j=1}^{n} A_j F_{ij}$ = the "accessibility index" for zone i.

The gravity model is mathematically formulated so that a production balance is maintained. In other words, the total trip production (row) for each analysis area as calculated from the model equal to the input trip productions. However, the totals trip attraction (column) for each zone output from the model will not necessarily match the desired input trip attraction values. Therefore, to attain an acceptable attraction balance, an iterative process is employed to adjust the calculated trip interchanges. In other words, although the sum of the trip productions and sum of the trip attractions add up to be the same, the total trip attractions (A_j) are not equal to the desired trip attractions. Therefore, further iterations are necessary.

After each application (iteration) of the gravity model, the adjusted total trip attraction (for each zone) to be used for the next iteration are calculated according to the following expression:

$$A_{jk} = \lfloor A_j . A_{j(k-1)} \rfloor / C_{j(k-1)} \tag{2.18}$$

Where A_{jk} = adjusted attraction factor for attraction zone (column) j, iteration k,

A_{jk} = A_j, when $k = 1$,

C_{jk} = actual attraction (column) total for zone j, iteration k,

A_j = desired attraction total for attraction zone (column) j,

j = attraction zone number, $j = 1, 2, 3, \ldots, n$,

n = number of zones,

k = iteration number, $k = 1, 2, 3, \ldots, m$ and

m = number of iterations.

In the trip distribution procedure, for many uses, the sufficient number of iterations and the adequate adjustment factor are required. Generally, the percent difference between the total trip attraction at the end of the each iteration and that originally input trip attraction for each zone, a 5 to 10 percent difference is acceptable.

3. Friction factor calibration

There are some functions generally used in gravity model for representing impedance as follows [48, 49]:

i. Negative power function:

$$F_{ij} = f(t_{ij}) = (t_{ij})^{-\alpha} \tag{2.19}$$

ii. Negative exponential function:

$$F_{ij} = f(t_{ij}) = e^{-\beta(t_{ij})} \tag{2.20}$$

iii. Tanner function:

$$F_{ij} = f(t_{ij}) = (t_{ij})^{\alpha}.e^{-\beta(t_{ij})} \tag{2.21}$$

where F_{ij} = the friction factor between zones i and j,

α, β = parameters to be estimated,

t_{ij} = travel time from origin zone i to destination zone j as the impedance (others can be distance, cost, etc.),

iv. Gamma function [50],

$$F_{ij} = a \times t_{ij}^{b} \times e^{c \times t_{ij}} \tag{2.22}$$

where F_{ij} = the friction factor between zones i and j,

a, b, c = model coefficients; in most cases, both b and c should be negative; a is a scaling factor and can be varied without changing the distribution,

t_{ij} = the travel time between zones i and j,

e = the base of the natural logarithms.

For example, the impedance factor considered is travel time due to its reasonable for passenger trip, while the cost data is not available. In the analysis, the relationship between a set of impedance (travel time) and friction factors (F_{ij}) is assumed a negative power function, then it can be written as:

$$F_{ij} = f(t_{ij}) = \gamma / t_{ij}^{\alpha} = \gamma.(t_{ij})^{-\alpha} \tag{2.23}$$

4. Zonal factor calibration

The zonal socio-economic adjustment factor (K_{ij}) is calculated by using formula

$$K_{ij} = R_{ij} \frac{1 - X_{ij}}{1 - X_{ij} R_{ij}} \tag{2.24}$$

where R_{ij} = ratio of observed trip to the gravity model result for the trips from zone i to zone j,

X_{ij} = ratio of origin-destination (O-D) trips to the total O-D trips leaving zone i

Equation (2.28) is applied if 10 percent to 40 percent of the trip is leaving a zone. For other conditions, R_{ij} should be used as the K-adjustment factor [44, 50].

2.6.2 Elasticity Concept and Sensitivity of Bus Service Demand

The improvement of quality of bus service is necessary to promote the bus service demand. The concept of elasticity in economics is applied to assess the sensitivity or change of bus service demand [22]. In the economics theory, the law of demand is illustrated in Figure 2.7. The law states that, everything else being constant, the quantity Q of goods or service that consumers demand decreases as their price P increases and conversely, when the price is reduced, the quantity demanded rises. As transportation system is a service, therefore, it is unable to avoid that the service is subject to market force. For instance, the drop in number of trips should be expected to occur following an increase in transit fare. On the other hand, decreases in parking fee would encourage car use.

The definition of price elasticity of demand is the ratio of the relative of change in the quantity demanded to the relative change in price. In other words, elasticity is percentage of change in response divided by percentage change in stimulus [5, 22]. Thus, the general form of elasticity is formulated as

$$E = \frac{dQ/Q}{dP/P} = \frac{dQ}{dP}\frac{P}{Q} \tag{2.25}$$

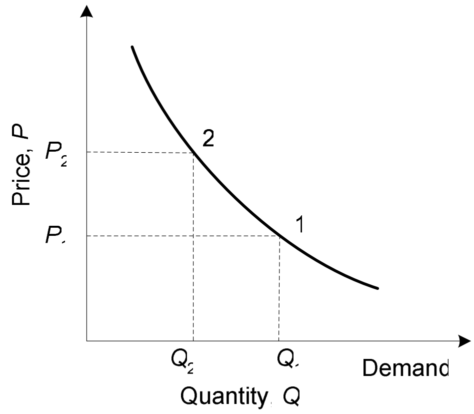


Figure 2.7 A hypothetical demand curve

The results of calculation may show a different sign. The negative sign (-) of elasticity reflects the fact that a percentage increase in price causes a percentage decrease in quantity. The price elasticity of demand is not constant for all points on the curves.

An upward and downward price change may result in an increase, a decrease, or a constancy of revenue, as the total revenue is the multiplication of quantity of demand and unit price (See Figure 2.8). Clearly, the fact can be described by the value of price elasticity of demand. Moreover, there are situations of demand sensitivity upon the implication of a price change on the total revenue of the supplier or operator as follows [5, 22, 51]:

a. Elastic (relatively sensitive) demand; if $E < -1$, means that the percent decrease in quantity is larger than the percent increase in price. In other words, the total revenue after the price increase decreases because the loss of sales volume outweighs the extra revenue obtained per unit sold. There is a negative relation between price and total revenue. In this case, an increase in price will reduce total revenue, but a decrease in price will increase total revenue.
b. Inelastic (relatively insensitive) demand; if $E > -1$, means that the total revenue after raising price increases. In this case, an increase in price will increase total revenue and a decrease in price will decrease total revenue. This is called positive relation.
c. Unitarily elastic demand; if $E = -1$, if the revenue derived from selling less units at a higher price is equal to the total revenue prior to raising the price, for instance, more units at a lower price. Although the price goes up or down, the

total revenue will remain the same. In other words, that price changes cause a proportional changes in consumption.

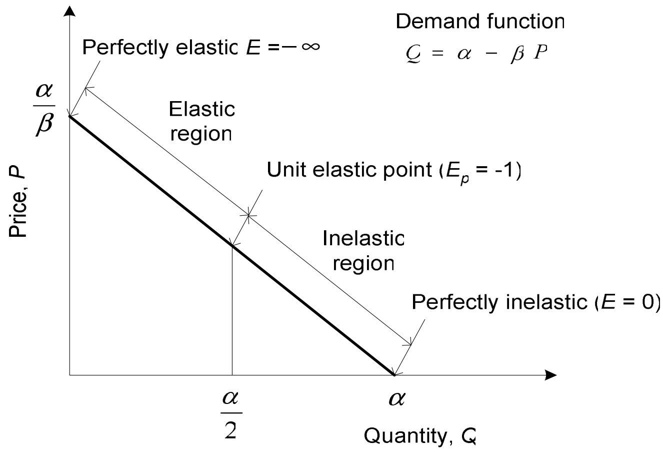


Figure 2.8 General case of a linear demand function showing elasticity

The form of demand can be a linear function or a non-linear. The linear demand function expresses the price elasticity,

$$Q = \alpha - \beta P \tag{2.26}$$

where, Q = quantity or volume or number of trips

P = price or bus ticket fare

α, β = parameter to be estimated

Meanwhile, the non-linear demand function (known as Kraft demand model) is expressed as,

$$Q = \alpha (P)^{\beta} \tag{2.27}$$

where, Q = quantity or volume or number of trips

P = price or bus ticket fare

α, β = constant parameters of the demand function

In a particular transit service, the demand function is assessed to be a function of fare F and travel time T [5]. As shown in (2.32), the demand function is called product form demand function because of some components involved. The exponent of the price components represents the elasticity of demand with respect to each component.

$$Q = \alpha F^{\beta} T^{\gamma} \tag{2.28}$$

The method of measurement of elasticity is by observing actual price changes in the system under study [5]. The price change is accounted carefully and properly for demand changes because there are more than one cost component. There are many factors other than price taking effect on demand change including many attributes of population and demographic change. Thus, it is important to assess separately the overall demand response to its corresponding individual components. Parody and Brand [52] as cited by Papacostas *et al*. [5] reported the study on forecasting demand and revenue for transit prepaid pass and fare alternative. A various elasticity of several user sub-groups was derived and used to predict the transit demand effects of alternative fare structures.

There are several equations that can be used to approximate the price elasticity of demand such as shrinkage ratio, mid-point elasticity and log-arc elasticity.

1. <u>Shrinkage ratio</u>

Elasticity is a ratio between percentage of change in quantity (units) and percentage of change in unit price (or other factors). The shrinkage ratio is defined as

$$E_{shr} = \frac{(Q_2 - Q_1)/Q_1}{(P_2 - P_1)/P_1} \tag{2.29}$$

where, P_1, P_2 : price before and after a situation

Q_1, Q_2 : quantity or ridership before and after

E_{shr} : shrinkage ratio

2. <u>Arc elasticity (mid-point formula)</u>

The arc elasticity or mid-point formula is computed as

$$E_{arc} = \frac{(Q_2 - Q_1)/(Q_1 + Q_2)}{(P_2 - P_1)/(P_1 + P_2)} \tag{2.30}$$

Note: P_1, P_2 : price before and after

Q_1, Q_2 : quantity before and after

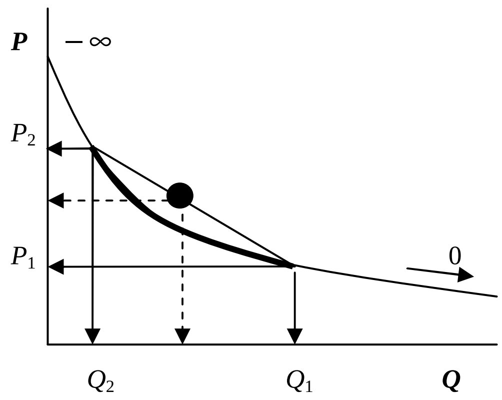
$-\infty$: perfectly elastic,

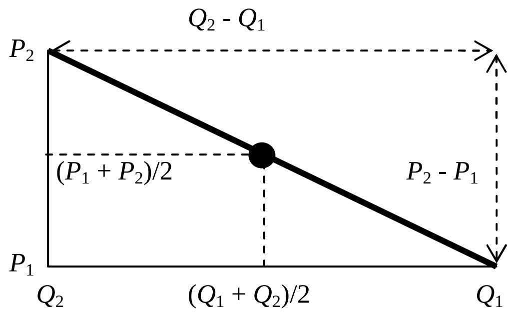
0 : perfectly inelastic,

-1 : change in demand equals change in “price”.

An elasticity $E = \beta$ means that every 1% of price change lost β % demand.

The elasticity based on mid-point elasticity formula is described in Figure 2.9.





Note: $-\infty$ = perfectly elastic, 0 = perfectly inelastic, -1 = change in demand equals change in "price". The elasticity β means that every 1% of price change lost β% ridership.

Figure 2.9 The illustration on elasticity equation

Mid-point elasticity formula:

$$E = \frac{(Q_2 - Q_1)}{[(Q_1 + Q_2)/2]} \div \frac{(P_2 - P_1)}{[(P_1 + P_2)/2]}$$
$$E = \frac{(Q_2 - Q_1)(P_1 + P_2)}{(Q_1 + Q_2)(P_2 - P_1)} \tag{2.31}$$

Where, P_1 : price before Q_1 : ridership before
P_2 : price after Q_2 : ridership after

3. Log-arc elasticity

The log-arc elasticity is calculated as

$$E_{\log-arc} = \frac{\log Q_2 - \log Q_1}{\log P_2 - \log P_1} \tag{2.32}$$

where, Q_1, Q_2 : quantity or observed demand change before and after a situation

P_1, P_2 : actual price before and after a situation

$E_{log\text{-}arc}$: log-arc elasticity

2.7 Summary

There are some important elements of transport in improving public transportation system such as transport demand, basic access and mobility and transportation option. Some transport modes supporting the public transportation are also important such as walking, cycling, ridesharing, transit, taxi, delivery services and telecommunications.

Their quality of service is determined by some factors such as availability, speed, frequency, convenience, comfort, safety, price and prestige.

By comparing many transportation modes in terms of characteristics of movement (speed) and accessibility, bus system is a kind of passengers transport modes which can operate at low to high speed but at medium accessibility. For instance, local bus can provide service at medium accessibility with relatively low speed, meanwhile the express bus operates at high speed with medium accessibility.

Public transportation is becoming important issues due to their contribution to public transportation to facilitate people mobility instead of using private car. Research on public transportation system and all aspects surrounding public transportation planning and operations is currently interesting for international community of researchers, practitioners, vendors, academia, industry, government and also users. Advancement in public transportation system has been contributed by development of technology in telecommunication and computation, for example, computer-aided scheduling system, automated vehicle location, automated passengers counting, etc.

The role of public transportation includes many aspects in economic development and quality of life in communities in worldwide. The vital contribution of public transportation includes the aspect of accessibility, health and happiness, economic growth, education and job training. To be well accessible, public transportation provides ideally equal opportunities and transportation for all people to access a place and around regional destinations regardless of age, ability, or income. Most public transportation systems aim to convey large number of people as quickly as possible, usually into or around a city centre.

There are stakeholders in relation with bus system operation such as users, operator/bus companies, regulator and society. They play a role in bus system planning, operation and management whether in a direct or indirect way. Therefore, many activities are generated well by the established bus service operation such as economic, tourism, education and many other informal sectors.

To analyze characteristics of bus services and to evaluate the quality of service, there are some standards for evaluating viability of bus operation such as World Bank standard (1987) [24], standard adapted by Vuchic (1981) [10] for comparison of technical, operational and system characteristics and the Transit Capacity and Quality of Service Manual (TCQSM 2003). The number of bus services characteristics include travel time (minute), headway (minute per vehicle), load factor (%), vehicle capacity (seats per bus), route distance (kilometer), route or trip time, operating speed (km per hour), headway (minute per bus), frequency (bus per hour) and the number of vehicle (bus).

TCQSM 2003 manual is available to evaluate transit capacity and quality of service (QOS). The quality of service (QOS) of bus system reflects transit performance measures. A number of quantitative and qualitative factors are considered for performance measures. A numeric performance measure converted into an A to F grade named level of service (LOS). The grade is used to explain how good a bus service is according to passenger's point of view. LOS A represents the best performance. Meanwhile, LOS F represents an undesirable condition from passenger's perspective or viewpoint. The LOS concept was introduced by HCM in 1965 and adopted by TCQSM, so that it is compatible. Clearly, there is a difference between QOS and LOS. QOS is the overall measured or perceived performance of transit service from the passenger's point of view. Meanwhile, LOS is a way to measure QOS. There are six ranges of values for a measure with grades from A to F.

The demand on public transportation is considerably affected by the public transportation service level. Public transportation service level is generally influenced by a number of factors such as accessibility, waiting time, journey time, reliability, punctuality, fare, information and the level of service. In reliability aspect, some parameters are generally measured such as on-time performance, service regularity, punctuality index and expected average waiting time.

The improvement of the bus service system planning and operation are made by following the steps and by considering the aspects below. Among the important aspects in bus service planning and operation discussed in this section are determination of route, number of fleets, number of bus stop, bus priority, bus lane and the elasticity of bus service demand. The elasticity of bus service demand can be measured by using many factors such as ticket fare, fuel price, income and service frequency.

The demand of bus service is analyzed in terms of the number of passenger per day. Trip distribution is estimated by applying gravity model. Impedance factor for calibration the model is travel time. Meanwhile, zonal socio-economic is reflected by K-adjustment factor. In addition, demand sensitivity is assessed with respect to the change in some ridership factors. The concept of elasticity in economic theory is applied to analyze the influence of change in ridership factors to the change in bus service demand. Three elasticity formulas used for estimation and evaluation of demand are shrinkage ratio, arc elasticity (mid-point elasticity formula) and log-arc elasticity.

According to the earlier summary about practical knowledge, theoretical background and solution approaches for solving research problems, with the fact of low service quality of stage bus, lack of data measurements and inadequate standard or evaluation framework encourage the study on the bus system service. Therefore, further study in proposing solution approaches and their measures of effectiveness are presented such as bus service characteristics analysis, performance indicators evaluation and improvement, bus service demand analysis and trip distribution of bus service demand.

CHAPTER 3
METHODOLOGY

3.0 Overview

The purpose of this chapter is to present a study approach and method of analysis in this research. The method of study includes determination of location, the standard of bus service and relevant manual, data collection method, sources of data, surveyor and data instrument procedure of survey, data compilation and method of analysis and evaluation. The content of this chapter is detailed particularly in each section and sub-section for competing methods. The end part is chapter summary.

3.1 Location of Study and Strategic Regional Development

Ipoh-Lumut corridor is part of Perak State area which lay over three districts such as Kinta, Perak Tengah and Manjung (See Figure 3.1). There is a highway of 82.6 km in length that plays an important role in socio-economic growth of Perak. There is a divided multiple lane highway that links Ipoh (center point of Perak) and Lumut (harbor or sea port, navy and tourism point). A set of information describing the profile of socio-economic development is indicated briefly in Table 3.1 and Table 3.2.

According to Rancangan Struktur Negeri Perak 2001-2020 [27], the category of land use development in this corridor included residential land, commercial, industrial, educational institution, agricultural, open space or recreation area, unused land or jungle and others (i.e. infrastructure, transportation facilities, etc.). For example, the composition of land usage for Manjung District generally covers:

i. 2.5% on development projects.
ii. 12% undeveloped (covers reserve swamp, reserve river or drainage), and

iii. 85.5% has the potential for development projects in the future which land agricultural land, mining areas or mined areas and unused lands.

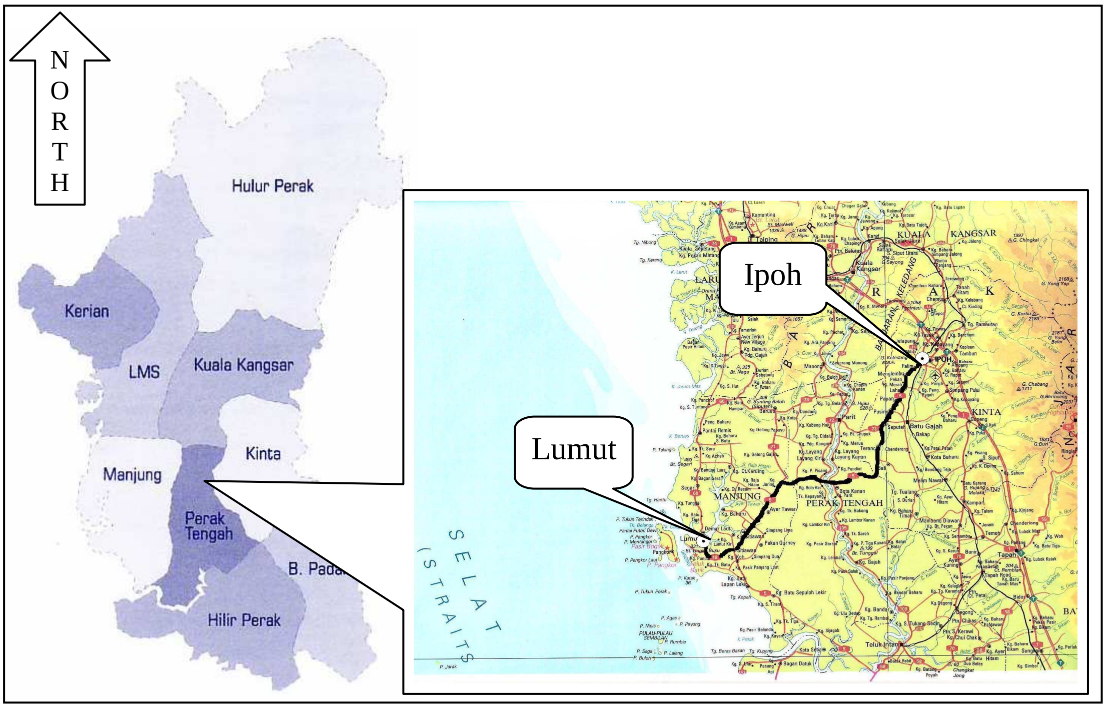


Figure 3.1 Districts map in Perak State and Ipoh-Lumut corridor

Source: Profil dan Data: Perak Darul Ridzuan [53]

Table 3.1 Profile of Perak State

No.	Description		Number	Unit
1	Areas		21,005	km^2
2	Population	(1991)	1.9	million
		(2000)	2.0	million
		(2004)	2.2	million
		(2007)	2.32	million
3	Growth		0.9	%
4	Urban proportion		60	%
5	District		9	
6	Small District		8	
7	Mukim		71	
8	Village		902	
	PBT (Pihak Berkuasa Tempatan) Negeri Perak		15	

Source: Profil dan Data: Perak Darul Ridzuan [53], Perak Population in 2008 [54]

Table 3.2 Areas and population of district

No.	District	Areas (km^2)	2002 Population (People)	2002 Density (People/ km2)	2008 Population (People)	2008 Density (People/ km2)
1	Batang Padang	2,712	159,083	59	180,014	66
2	Hilir Perak	1,728	198,743	115	217,848	126
3	Hulu Perak	6,563	86,462	13	107,201	16
4	Kerian	958	159,430	167	181,568	190
5	Kinta	1,958	735,030	375	831,888	425
6	Kuala Kangsar	2,541	150,244	59	167,662	66
7	Larut, Matang & Selama	2,095	249,455	119	315,976	151
8	Manjung	1,171	199,809	171	240,446	205
9	Perak Tengah	1,279	85,532	67	108,687	85
	Total	21,005	2,023,788	98	2,351,290	112

Source: Population 2002 and Projections 2008 based on 2000 population census [54]

As published by UPEN [53], the profile of infrastructure in Perak based on its type was shown in Table 3.3. The length of highway infrastructure in 2004 was about 233 km. Other roads in sequence were local bituminous streets of 6,700 km and rural road of 1,600 km. Total length of road was 8,533 km. Despite roads, Perak had other transport infrastructure such as railway (single), double track railway, runway, cargo terminal and sea port (harbour).

Table 3.3 Profile of infrastructure in Perak

No.	Infrastructure type	Characteristics	Units
1	Lebuhraya	233	km
2	Jalan bertar	6,700	km
3	Jalan luar bandar	1,600	km
4	Landasan keretapi	262	km
5	Landasan rel berkembar	174	km
6	Lapangan terbang		
	- Ipoh	Lapangan terbang domestic	
	- Pangkor	Short Take Off Landing (STOL)	
7	Pelabuhan darat	Ipoh Cargo Terminal (Dry Port)	
8	Pelabuhan laut	480	m (panjang dermaga)

Source: Profil dan Data: Perak Darul Ridzuan [53]

In each Perak district, the public transportation system was also supported by a number of bus stations and sub-terminals. For instance, in the location of study there were Medan Gopeng bus station, Medan Kidd bus station, Seri Iskandar bus terminal, Manjung bus terminal and Lumut bus station. Medan Gopeng, Manjung and Lumut were utilized for intercity express bus, meanwhile, Medan Kidd and Seri Iskandar bus station were for city and local bus within Perak State. Public transportation in Ipoh-Lumut corridor was served by operator, Perak Roadways Sdn. Bhd. Perak Roadways served directly from Ipoh to Lumut route directly without entering Pusing and Tronoh town. Another operator which operated bus on the same highway but of different origin and destination was General Bus. General Bus served Ipoh-Pusing-Tronoh-Sitiawan. The kind of service for both Perak Roadways and General Bus was called stage bus, or in Malaysia language, it was called “bas berhenti-berhenti”. For comparison, according to LPKP (Lembaga Pelesenan Kenderaan Perdagangan), in Malaysia there were three kind of bus operation categories such as express bus, stage bus and city bus [55].

3.2 Study Methodology by World Bank

Methodology for this study is guided by World Bank standard [24]. In specific aspect, World Bank standard does not cover adequately the quality of service and reliability aspects related to current issues and challenges. Therefore, an adaptation from other manual and standard is required. In general, World Bank suggested the study methodology with titled, “Bus Service: Evaluation and Improvement Study” as described below.

1. Draft terms of reference
2. Objectives: improve the viability and quality of service provided by bus company
3. Scope: geographic, technological and institutional
4. Problem to be addressed
5. Available data sources
6. Study approach
7. Study methodology
    a. General description of the company
    b. Operational environment
        i. the degree of government control over access to the markets
        ii. the degree of control or influence of cooperatives and unions
        iii. an indication of public and political attitudes
        iv. details of competition from other operators and transport systems
        v. traffic conditions along routes and at stops, terminals and interchanges
    c. Study period
    d. Assessment of demand
    e. Operational performance

f. Financial performance
g. Standard of service
h. Measures to effect improvements
   i. organization size and structure: including responsibility and accountability of managers
   ii. personnel management: training, hire and fire procedures, pay and benefits, discipline and incentives
   iii. routes and services: quality, quantity, variety
   iv. passenger facilities: stops, terminals, interchange facilities
   v. bus facilities: depots, parking, priority measures
   vi. choice and numbers of vehicles
   vii. procurement of vehicles, spares and materials
   viii. maintenance procedures
   ix. fares, fare collection and security
   x. information and accounting systems; cost control, route costing
   xi. role of government: policy, regulation and control, facilities and assistance (this item should be excluded if a separate study of government policy is to be undertaken)

8. Schedule and reporting

9. Staffing

Team of expertise should be provided in the study:

a. public transport planning
b. bus operations and management
c. bus maintenance and servicing
d. financial analysis and costing

10. Government responsibilities

   i. to give the consultants access to all available data relevant to this study
   ii. to provide office space, secretarial and drafting help, transportation and office equipment necessary to conduct the study quickly and efficiently

11. Other sections: standard clauses

Additionally, Figure 3.2 and Figure 3.3 show the details diagram of the methodology. This diagram shows clearly the structure and flow of study which mainly consists of four parts such as,

Part 1: Title of project on "Bus Service: Evaluation and Improvement Study".

Part 2: Study methodology

Part 3: Key operating performance indicators

Part 4: Quality of service indicators

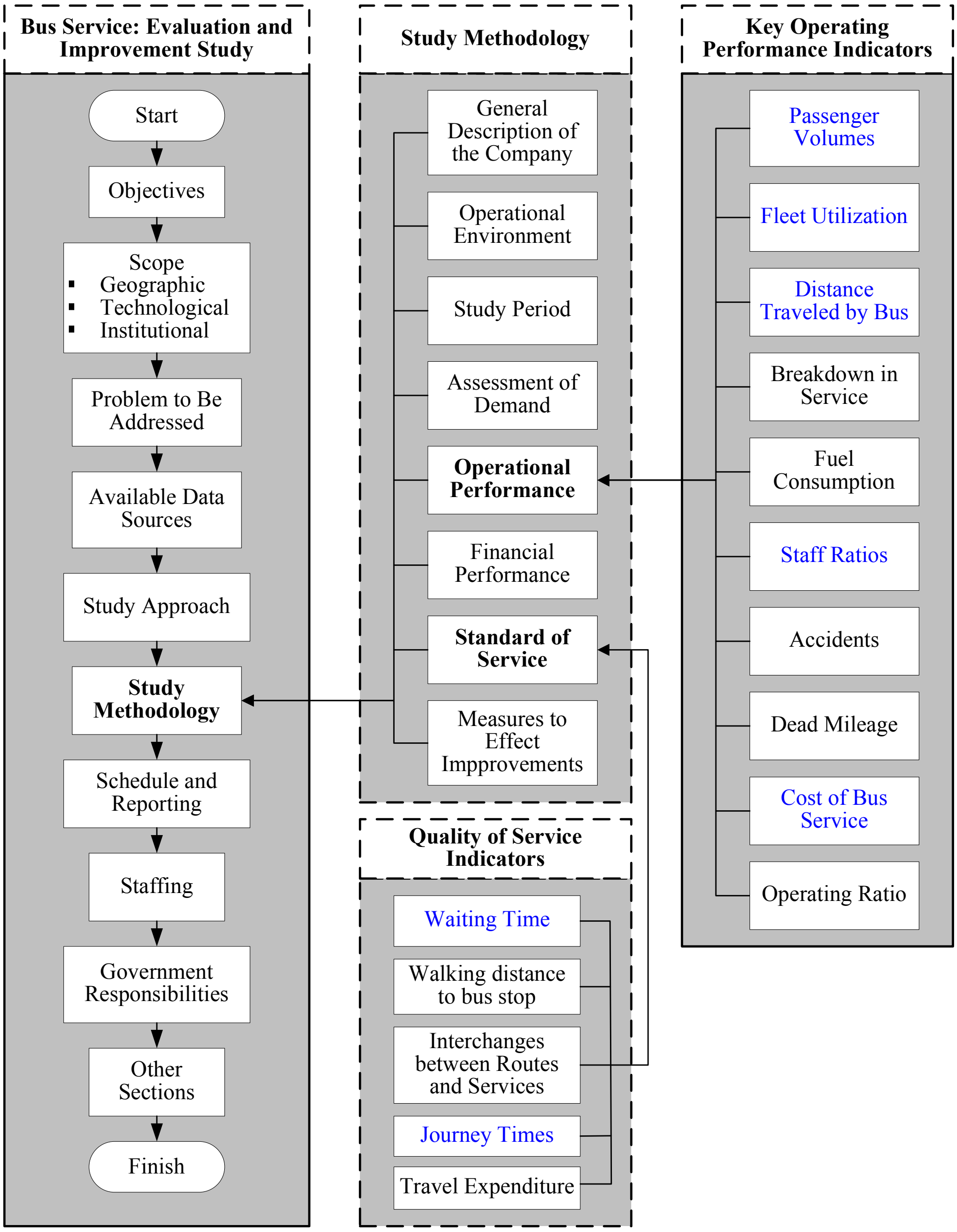


Figure 3.2 Flowchart of bus service evaluation and improvement study

Source: World Bank technical paper number 68 [24]

The role of government in public transportation is important to provide regulation for the operation and to be responsible of the public transportation development sustainability. The government regulation and responsibility on the public transportation development are detailed as in Figure 3.3.

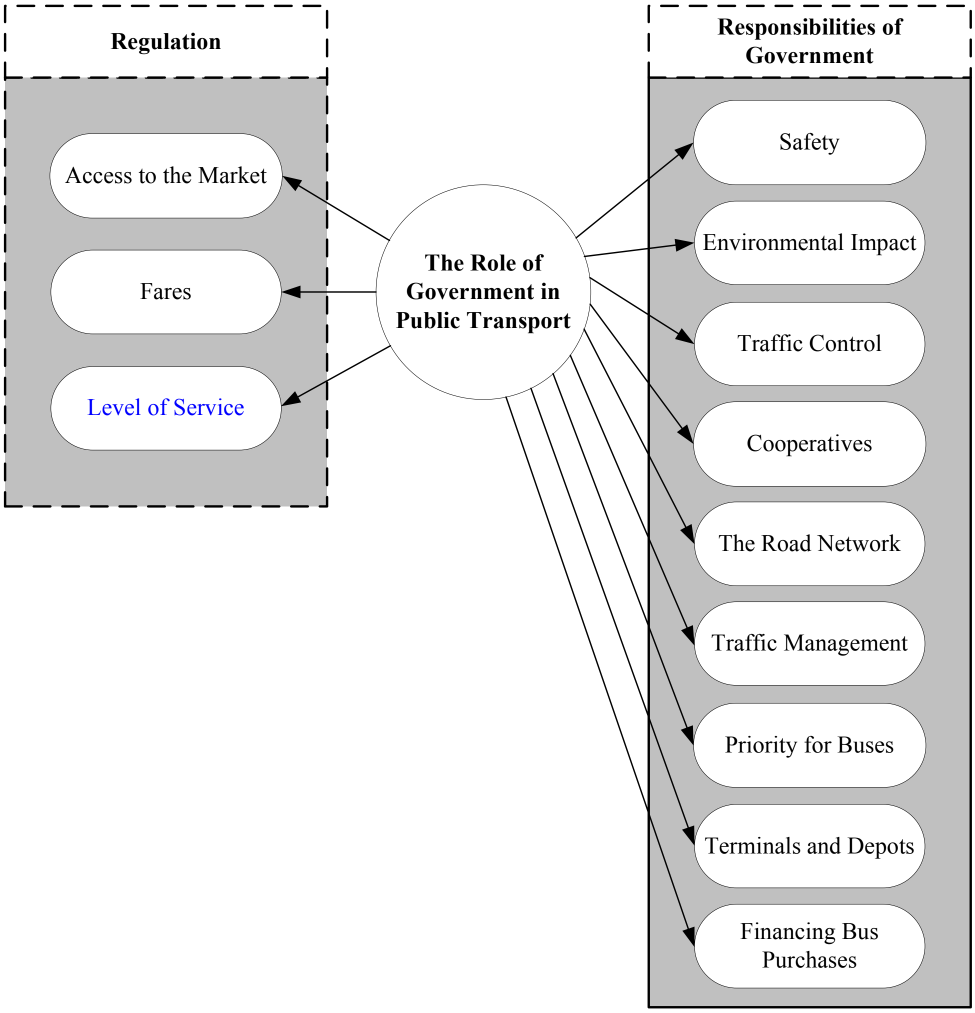


Figure 3.3 The role of government in public transportation

Source: World Bank technical paper number 68 [24]

3.3 World Bank Standard

According to World Bank technical paper number 68 [24], there are two important guidance to refer in this study such as the operational performance indicators and indicators of service quality. Not all the components and criteria of the standard are applicable. However, a number of elements are chosen and some modifications are necessary for application. The methodology of this study refers some criteria of evaluation from World Bank standard. In addition, to cover the lack of criteria from this standard, then criteria from other standard is adapted.

3.3.1 Operational Performance Indicators

In operation, the performance indicators of bus service which comprise a number of components and criteria used for evaluation are summarized in Table 3.4 below.

Table 3.4 Operational performance indicators

No.	Components and Criteria		Values
1.	Passengers volumes		
	Average number of passengers per operating bus per day		
	Type of bus	Crush capacity	
	- Single deck	80	1,000-1,200
	- Single deck	100	1,200-1,500
	- Single or double deck	120	1,500-1,800
	- Articulated or double deck	160	2,000-2,400
2.	Fleet utilization		
	Buses in service during the peak, as a percentage of the total fleet:		80-90
3.	Distance traveled by buses		
	Average kilometers per bus per day		210-260
4.	Breakdown in service		
	As a percentage of buses in operation:		8-10
5.	Fuel consumption		
	Liters per 100 kilometers		
		Minibuses	20-25
		Buses	25-50
6.	Staff ratios		
	Staff per operating bus:		
		Total staff	3-8
		Administrative	0.3-0.4
		Maintenance staff	0.5-1.5
7.	Accident rate		
	Accidents per 100,000 bus kilometers:		1.5-3.0
8.	Dead mileage		
	Percentage length of bus journey not earning revenue:		0.6-1.0
9.	Cost of bus services		
	Total cost (operating cost, depreciation and interest) per passenger-kilometer		
		Mixed traffic:	US c 2-5
		Segregated busways:	5-8
10.	Operating ratio		
	Total revenue divided by operating cost including depreciation		1.05:1-1.8:1

3.3.2 Quality of Service Indicators

To measure quality of service of bus system service, the criteria and measurements are referred to World Bank standard as contained in Table 3.5 below.

Table 3.5 Quality of service indicators

No.	Criteria and Measurements	Values	Unit
1	Waiting time		
	Passenger waiting time at bus stops		
	- Average	5-10	minutes
	- Maximum	10-20	minutes
2.	Walking distance to bus stops		
	- Dense urban areas	300-500	m
	- Low-density urban areas	500-1,000	m
3.	Interchanges between routes and services		
	The number of times a passenger has to change buses or other mode on a journey to or from work:		
	- Average	0-1	times
	- Maximum (less than 10% of commuters)	2	times
4.	Journey times		
	Hours traveling each day to and from work:		
	- Average	1.0-1.5	hour/day
	- Maximum	2-3	hour/day
	Journey speeds of buses:		
	- Dense areas in mixed traffic	10-12	km/h
	- Bus-only lanes	15-18	km/h
	- Low-density areas	25	km/h
5.	Travel expenditure		
	Household expenditure on travel as a percentage of household income:	10	%

3.4 Transit Capacity and Quality of Service Manual

Beside World Bank standard, there is other standard to refer. In this study, other criteria are also taken from Transit Capacity and Quality of Service Manual (TCQSM 2003). This manual is useful to evaluate transit capacity and quality of service (QOS). The transit performance measures are reflected by quality of service of existing system. There are two frameworks on measuring the quality of service (QOS) such as fixed-route QOS framework and demand-responsive QOS framework. A number of QOS criteria used for evaluation is covering headway or frequency, hours of service, service coverage, on-time performance (as a parameter of reliability), headway adherence or punctuality index (reliability parameter) and transit-auto travel time.

3.5 Study Approach and Method of Analysis

Flows diagram as in Figure 3.4 shows the study approach and analysis method. Study methodology and measurements of bus service characteristics and performance adapted from World Bank standard (See section 3.2 and 3.3) and criteria of quality of service from TCQSM (See section 3.4) are referred for the analysis of bus service characteristics, operational performance indicators and quality of service indicators. The main steps of the study include:

a. preliminary data inventory and proposal,
b. literature review,
c. data collection (secondary and primary),
d. preliminary survey for identifying problem, condition current bus service and verify the method of study,
e. main survey for collecting data of bus service operation and passenger loading,
f. profile of study area and preliminary analysis: explaining local, regional and national condition of transportation development (motorization and public transportation),
g. analysis of bus service characteristics: using statistical methods such as Auto-Regressive Integrated Moving Average (ARIMA), Multiple Linear Regression (MLR) and Statistica Neural Network (SNN) model,
h. analysis of bus service performance: using statistical parameters such as Mean Absolute Relative Error (MARE), Mean Absolute Percentage Prediction Error (MAPPE) and Analysis of Varian (ANOVA),
i. analysis of bus service improvement strategy: using simple regression, Multiple Linear Regression (MLR), Kraft Demand model and gravity model,
j. analysis of elasticity and sensitivity of bus service demand in short term period, and
k. conclusions and recommendations.

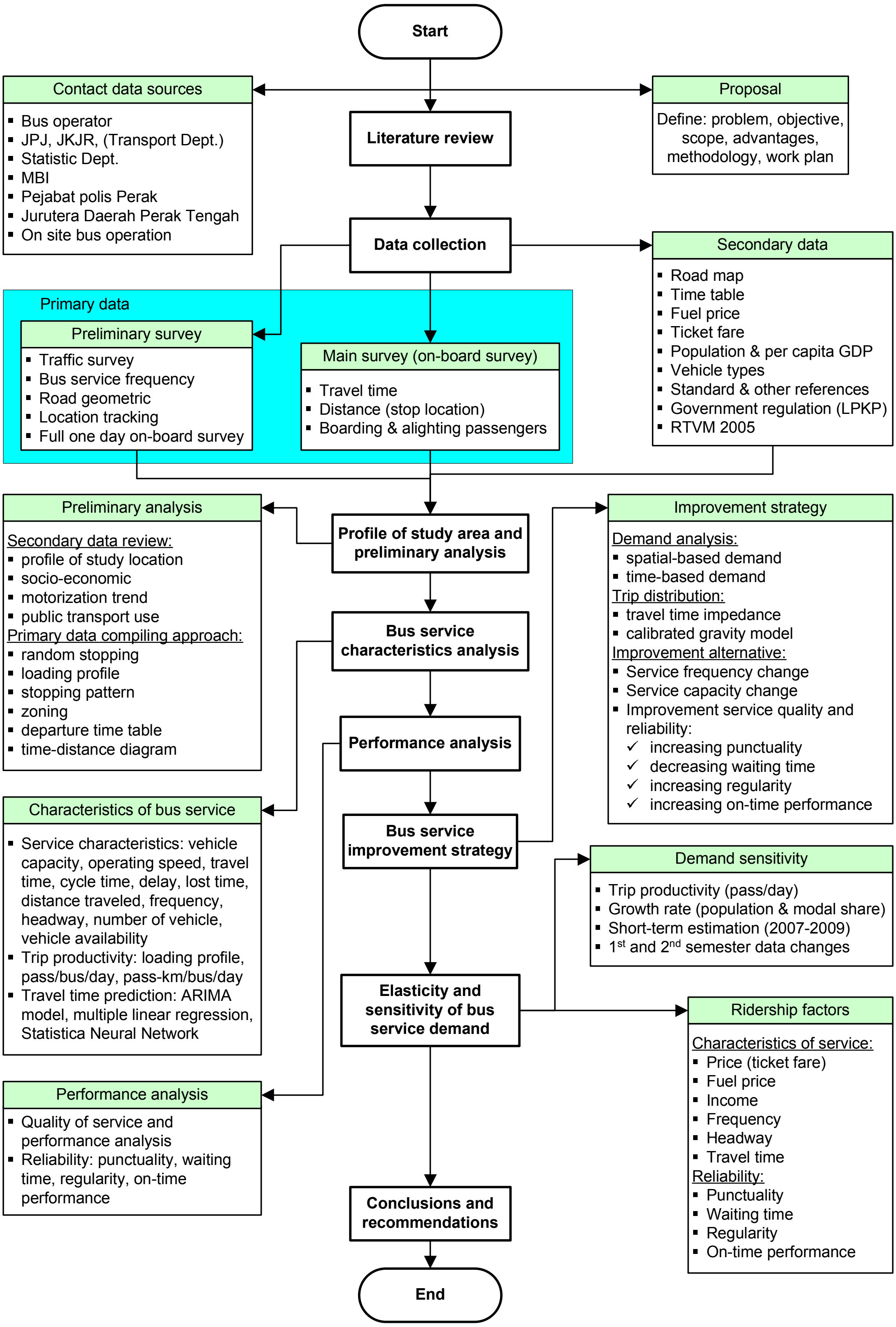


Figure 3.4 The flow diagram of study approach and analysis method

3.6 Data Resource and Data Collection Method

Secondary data include: project reports, road map, Rancangan Struktur Negeri Perak 2010 [27], road geometric, RTVM 2005 [28], time table, ticket fare and vehicle characteristics. Meanwhile, primary data for analysis which is collected from field work/investigation are including:

1. Traffic volume count for total traffic
2. Travel time survey for total traffic
3. Tracking location/point for example bus stations, bus stops, junction & other stop locations
4. Headway survey for bus (at check points)
5. Travel time for bus (on board survey)
6. Boarding & alighting of passengers for bus (on board survey)

Beside some secondary resource data above, some data collection method are applied for collecting primary data. The primary data is obtained by conducting field observation and surveying based on timetable as shown in Figure 3.5 to Figure 3.7. Data to be analysis includes all the primary and secondary data above regarding to the respective analysis in Chapter Four, Five and Six.

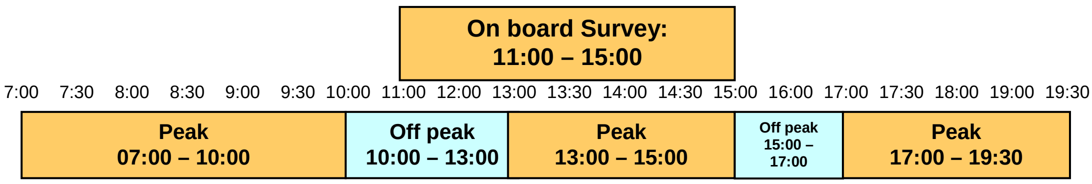


Figure 3.5 Timetable and time period of survey

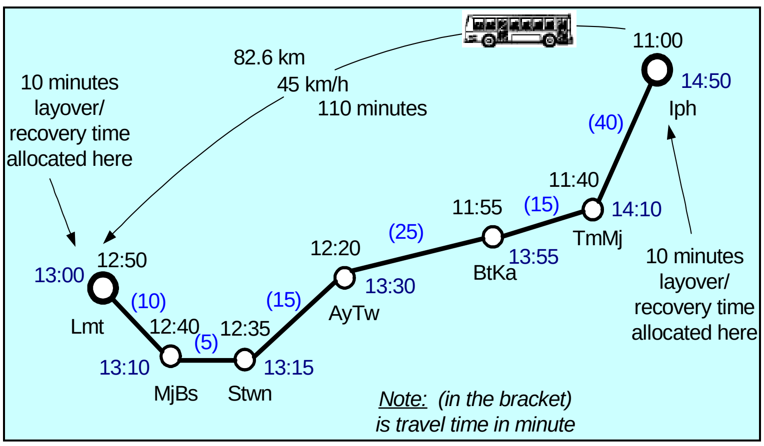


Figure 3.6 Location, distance, speed, travel time and schedule

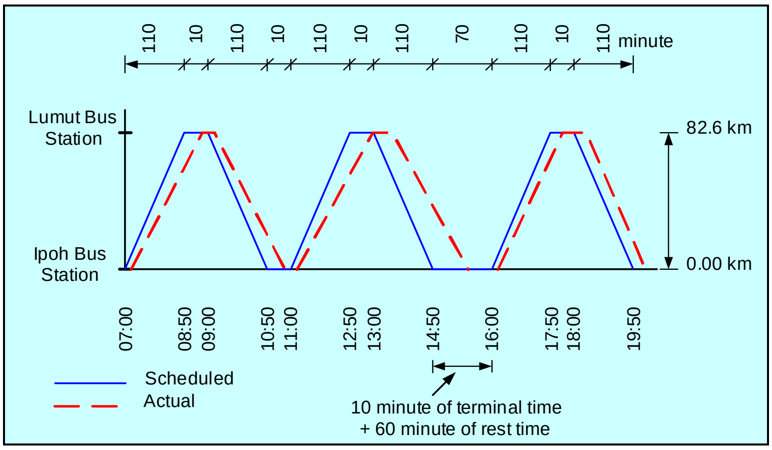


Figure 3.7 Time-distance model

3.7 Surveyor and Instrument

Surveyor is necessary to collect data. Data collection was performed by surveyor which categorized as follows:

1. Secondary data collection — 1 surveyor
2. Preliminary survey: road geometric and tracking location — 2 surveyors
3. Traffic survey:
   a. Volume count and vehicle classification — 4 surveyors
   b. Speed study — 2 surveyors
4. Bus service frequency (headway) survey — 2 surveyors
5. Boarding and alighting of passengers (on-board survey) — 1 surveyor

Surveyors were facilitated with a number of instruments and stationery for data collection. A number of instrument used for data collection are as follows:

1. Handheld GPS (Etrex Legend, Garmin) and its software
2. Motor cars/motorcycles
3. Data sheet
4. Stopwatcth
5. Clipboard
6. Road map

3.8 Procedures of Survey

The data for analysis was collected through a series of field observation. The surveys consist of preliminary survey, traffic survey, service frequency/headway and passenger surveys on the Ipoh-Lumut bus routes.

3.8.1 Preliminary Survey

The main purpose is to collect secondary data such as road map and to perform bus route tracking (by handheld GPS) and full one day on board survey (workday). The results is used to decide the method of main data collection about boarding and alighting passengers for one week and monthly over 2007, during peak session in typical workday and weekend basis.

3.8.2 Traffic Characteristics Survey

Traffic survey was carried out to describe the general traffic condition. Volume counting and travel time survey was done during morning, midday and evening period. The vehicle classification referred to the Road Traffic Volume Malaysia (RTVM 2005) [28]. From the data collected, analysis was done to obtain the traffic composition, volume and speed.

3.8.3 Service Frequency Survey

In the service frequency (headway) survey, observers were located at road sides to record bus numbers and the times the buses passed the observation points. The observation was conducted from early morning until afternoon while the buses were operating (normally from 07:00 to 21:00) for a minimum of two days representing workdays and weekend. Since the bus frequency is low (once every a few minutes), one observer was capable of recording bus movements in two directions.

3.8.4 Passenger Survey: Boarding and Alighting

On the passenger survey, the bus route was observed previously by using handheld GPS (Etrex LEGEND, Garmin), so it can be identified the name and distance of bus stop or others point of stop location. The points located between two main bus station (Ipoh and Lumut) indicate the passenger movements and the locations of passenger boarding and alighting.

The observer sited inside the bus and records the number of passengers boarding or alighting at or between points. The observer recorded the point/location code into GPS where passengers get in or out. This task was done repeatedly between the two terminals (start and end points) as long as the buses were operating, but the observer did not need to take the same bus. Since intercity buses have one door for getting in or out, then only one observer was required to be located near the front door.

The numbers of boarding and alighting passengers at each bus stop were collected during periods, 07.00-21.00 (full one day) and 11.00-15.00 (one week and one year). For Ipoh-Lumut bus route, the operation of bus route was evaluated from the data of the on-board survey. The result of boarding and alighting analysis shows the passengers loading profile.

From the data collected, analysis was performed and the following indicators become available:

a. time headway (minute),
b. cycle time (minute),
c. number of trips (trip/bus/day),
d. travel distance per bus per day (km/bus/day),
e. number of passengers carried per trip (pass/bus/trip),
f. average travel distance per passenger (km/pass),
g. the load factor (%) and
h. the number of passengers carried per bus per day (pass/bus/day)

The analysis was continued to obtain the bus service quality and level of service. The important service quality discussed including on-time performance, service regularity, headway analysis, punctuality index and level of service.

3.9 Characteristics of Bus Operation

To analyze the characteristics of bus services, the principle data of bus operation were collected from field surveys such as fleets characteristic, route distance, travel time, headway and load factor [17, 18]. Those data are briefly explained as follows:

a. Vehicle capacity; vehicle capacity is a number of seats depended on the bus type, except driver's seat and indicated with unit of seats/bus.

b. Route distance; the distance of bus route between origin (bus station) and destination (bus station) is measured in kilometer. Detail distance of bus stop or point of stop location within the route is measured by using handheld GPS (Etrex LEGEND, Garmin). See more detail the example in Figure 3.8.

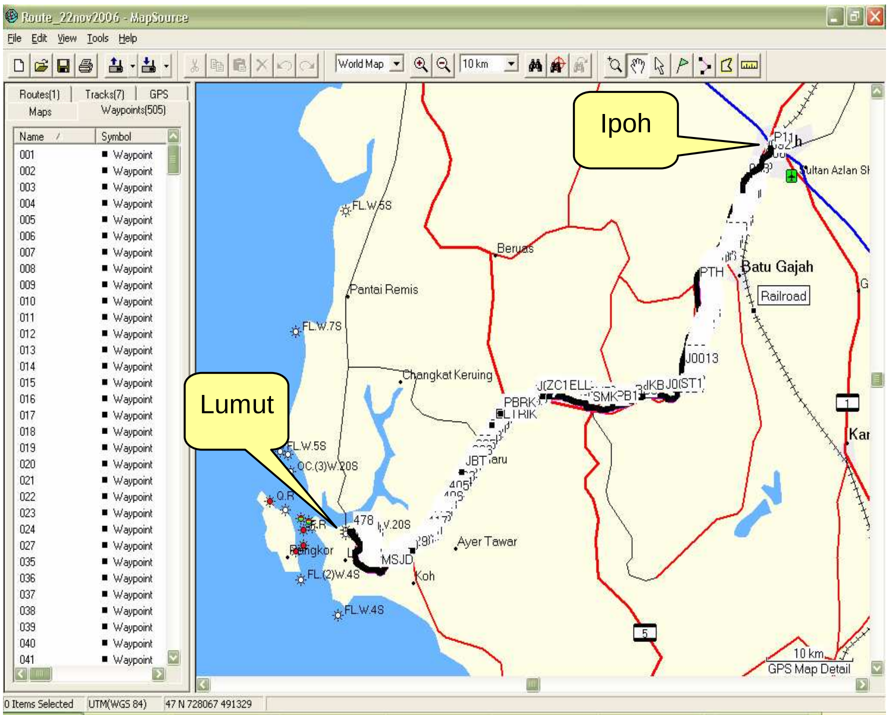


Figure 3.8 Tracking of bus stop, stop point and landmark in Ipoh-Lumut corridor

c. Route time; total trip time (one-way trip) is recorded from origin to destination include run and stop time, generally use unit of hour or minute.

d. Operating speed; operating speed is calculated from route distance divided by route time and measured in km/hour.

e. Headway; bus travel time survey is performed along the Ipoh-Lumut bus routes. Ipoh-Lumut bus route, operated with regular bus. The two buses are operated whether with air-conditioned bus or non-air conditioned bus. Observing stations (or bus stops) is selected along this bus route and bus stations. The arrival and departure time of bus is also recorded during the survey period from origin to destination. According to the data, the average headway can be analyzed.

f. Frequency; frequency is calculated from the data headway (minute per bus). Frequency equals to 60 divided by headway and measured in unit of bus per hour.

$$F = \frac{60}{H} \tag{3.1}$$

Where, F = frequency in vehicle per hour; and H = headway in minute

g. Number of vehicle; the number of vehicles, or fleet size needed to serve a route can be determined based on the route time [22]. Thus,

$$t_R = \frac{D}{V} \tag{3.2}$$

Where, t_R = route time travel (hour); D = route distance (km); V = operating speed (km/h).

The cycle time is formulated as

$$CT = (t_{R1} + t_{R2}) + (t_1 + t_2) \tag{3.3}$$

Where, CT = cycle time (minute); t_{R1}, t_{R2} = route time or travel time (two-way trip), t_1, t_2 = layover, recovery time or terminal time.

Cycle time (CT) is computed from the total time (two trips between two terminals), consist of route time and terminal time, standing time, lay over time. A minimum layover and recovery time is provided at the end of each route time. The lay over time (terminal time, etc.) is 10-15% of total route time (with considering the weather and vehicle condition).

The number of vehicles needed (fleet size) can be determined by formula

$$K = \frac{CT}{H} \tag{3.4}$$

Where, K = the number of vehicles; H is headway in minute. This number is rounded up.

The number of buses which consist of required, available and operating number. The available and operating number of buses data is obtained from the bus operators. Required or optimum number of bus is calculated from total cycle time divided by average headway. Availability is the operating number divided by available number of bus. Ratio of bus number is ratio between the operating to the required numbers.

h. Lost time; lost time is different between observed cycle time (CT_{obs}) and calculated cycle time (CT_{cal}). Cycle time consist of route time and lay over time. Lay over time is time period to serve a variety function (change driver, administrative purposes, preparation next run, to follow the schedule, etc.). Lay over time is taken normally 10-15% of the total travel time for calculating the calculated cycle time.

i. Boarding and alighting of passengers; the numbers of boarding and alighting passengers each bus stop are collected along the bus route in the morning, midday and evening time periods, for example 07:00-21:00. This data collection method is called on-board survey. For a case, the characteristic of bus service operation is evaluated by using data collected form the on-board survey. The result of boarding and alighting analysis shows the passengers loading profile.

3.10 Bus Service Analysis and Evaluation

Bus service analysis and evaluation was performed by referring to the World Bank standard. Some criteria adapted from World Bank standard are shown in Table 3.6. Meanwhile, TCQSM method is referred for other criteria on quality of service and reliability which are available in World Bank standard. Other references are also used to evaluate the respective criteria as in Table 2.8 and Table 2.7.

Table 3.6 Performance indicator of operational bus service

No.	Criteria	Parameter	Standard
1.	Rate of operated-available vehicle ratio	Ratio between number of operating vehicle and number of planned vehicle or available (%)	80-90
2.	Utility of vehicle	Average of traveled distance every day (km/day)	210-260
3.	Number of passenger	Number of passenger loaded each bus per day (persons/bus/day)	440-525
4.	Productivity of management	- number of administrative staff / bus	0.3-0.4
		- number of workshop staff / bus	0.5-1.5
		- number of total staff / bus	3-8
5.	Rate of accident	Number of accident each 100.000 km traveled distance (accident/100.000 bus-km)	1.5-3
6.	Rate of upholding or preservation	The percentage of number of bus in preservation to the total bus operated (%)	8-10
7.	Fuel consumption	The volume of fuel consumed each bus per 100 km of travel distance (liter/bus-100 km)	25-50
8.	Operating ratio	Ratio between revenue and operating cost (depreciation included)	1.05-1.08
9.	Load factor	Ratio between number of passenger and capacity of bus (number of seats) in a period of time (%)	70
10.	Number of transferred passenger	- no transfers/transit	> 50%
		- 2 transfers (twice)	< 10%

Source: World Bank Technical Paper Number 68: Urban Transport Series [24]

Table 3.7 Performance and characteristics of regular bus (RB)

No	Parameters	Units	Standard
1.	Vehicle capacity	seats/bus	40-120
2.	Frequency	bus/h	60-180
3.	Passenger capacity of route	pass/h	2400-8000
4.	Operating speed	km/h	15-25
5.	Lane width (one-way)	m	3.00-3.65
6.	Vehicle control	-	man/vis
7.	Reliability	-	low-med
8.	Safety	-	med
9.	Station spacing	m	200-500

Note: man : manual, vis : visual, med : medium

Source: Vuchic (1981) - Adapted for regular bus [22]

Table 3.8 World Bank Standard for bus performance

No	Parameters (units)	Standard
1.	Headway (minutes)	1-12
2.	Travel distance (km/bus/day)	210-260
3.	Number of passengers (pass/bus/day)	440-525
4.	Load factor (%)	70
5.	Availability (%)	80-90

Source: Arintono *et al.* [17] and Sulistyorini [21]

3.11 Transit Performance Measures

The measurement of quality of service is important to evaluate the transit performance measures. As mentioned in section 2.4.2, TCQSM is used as manual to evaluate transit capacity and quality of service (QOS). A number of quantitative and qualitative factors are used to evaluate particular aspects of transit service.

3.12 Summary

This section summarizes briefly the main points of study methodology. The method of analysis is summarized as follows:

1. Characteristics of traffic cover composition of traffic, traffic volume and average speed.
2. Bus service characteristics include vehicle capacity, distance, route time, operating speed of bus, headway or frequency, number of trips and traveled distance, cycle time, number of passengers, average traveled distance per passenger, load factor, number of buses, delay and lost time.
3. Service performance indicators consist of quality of service, reliability (on-time performance, regularity, punctuality index, headway adherence) and expected average waiting time.
4. Analysis of bus service improvement strategy covers demand analysis, trip distribution, improvement strategy, elasticity and sensitivity analysis of bus service demand.

CHAPTER 4
DESCRIPTION AND PROFILE OF STUDY AREA

4.0 Overview

This chapter with title description and profile of study area contains overview of Perak development, population and economic development, infrastructure of transportation, public transportation, terminal and bus stop, existing transportation system, bus service facilities and summary of this chapter.

4.1 Overview of Perak Development

In this section, Perak State development strategy is briefly overviewed. Perak boundaries and regional position are important aspect bringing Perak to a dynamic role in regional and national development. In hierarchy functions of urban, Ipoh (Perak State capital) is an intermediate (connective) growth conurbation. There are number of strategic development centre in Perak State.

4.1.1 Boundaries Area and Regional Position of Perak

Ipoh city is an important part of Perak State within the northern development region as identified in National Plan’s Urban Development Strategy for the country. Ipoh is strategically located mid-way between Penang and Kuala Lumpur, so that Ipoh appears to have taken on a dynamic role in the drive for regional development. Penang is national regional centre whereas Kuala Lumpur is national centre (See Figure 4.1).

In the regional development of Perak State, there are Ipoh (a state regional centre), Taiping, Lumut and Teluk Intan (state sub-regional centre). Perak also include several major local centres like as Gerik, Kuala Kangsar, Kampar, Bidor, Slim River and Tanjung Malim. The principal growth of Perak State includes area such as Ipoh, Kuala Kangsar and Kampar.

The structure plan proposed for Ipoh is a balanced development strategy. Since the balanced development strategy proposed the development of new growth centers and of the city fringes, the plan recognized the need for related road upgrading and new roads to serve them. Under this strategy the central planning area (CPA) is designated main commercial, administrative and financial centre to meet the needs of the Kinta Valley. A series of sub-centers and local centers within the city were proposed catering for local needs and in line with the policy to create a centre hierarchy. New centers of growth were identified in the Jelapang, Menglembu and Bercham/Tambun areas.

Key features of the future network include the Ipoh-Lumut by pass (under construction) and a proposed ring road around the central planning area (CPA). In the future context of industrial development, Ipoh will become the the administrative and commercial centre rather than the industrial hub. The scatter of industrial land will be around Ipoh. The sub-regional provision of industrial land outside Ipoh with their developing new growth centers are Chemor, the Ipoh-Batu Gajah-Lumut corridor and Simpang Pulai corridor. This sub-regional will help the State meet its programme for continued growth in industrial employment. The urban functional hierarchy for the Northern Region is shown in Figure 4.1. And, Figure 4.2 shows the industrial corridor (corridor B) which includes: Ipoh – Bandar Seri Iskandar – Lumut, where the study of bus service was undertaken.

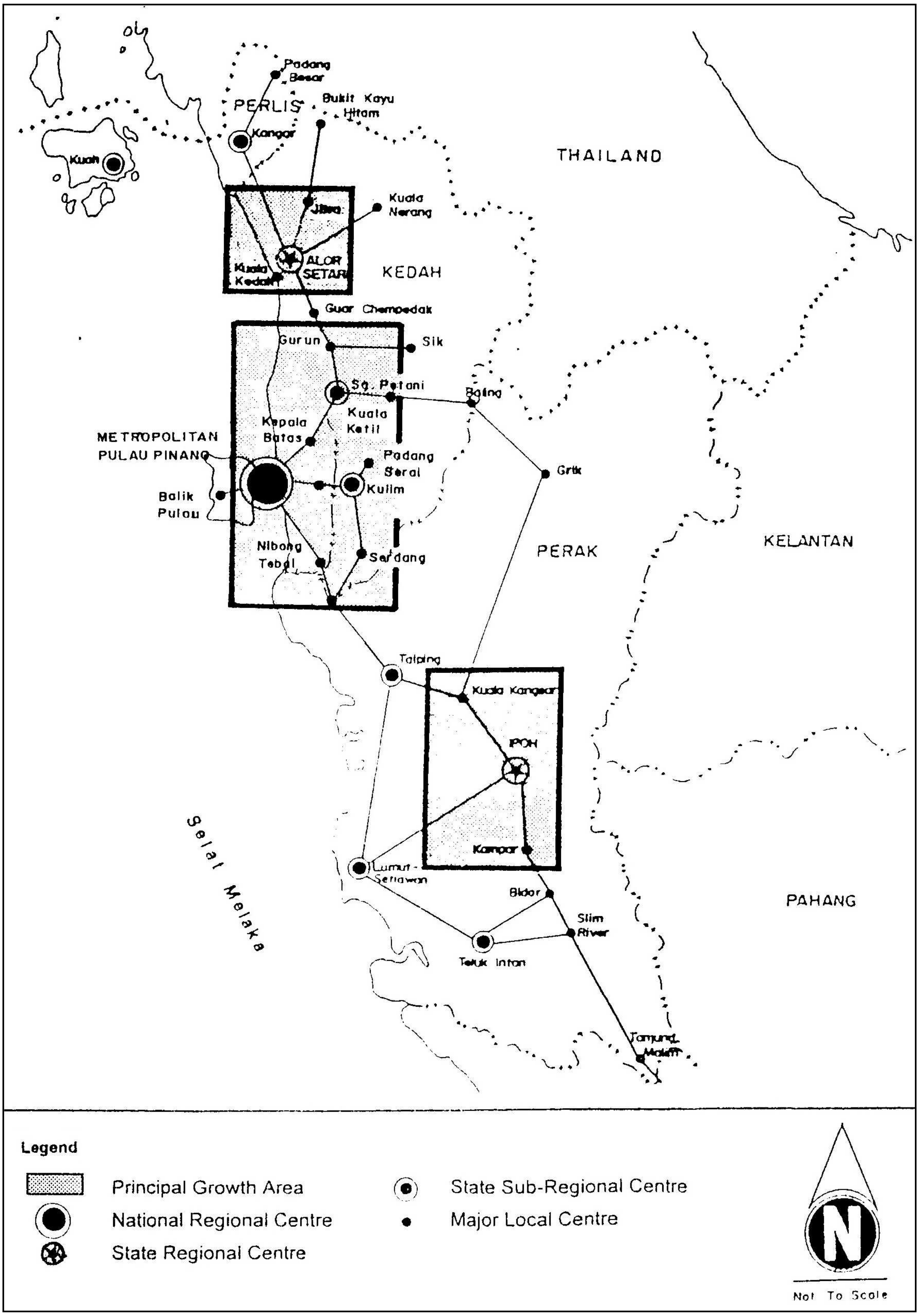


Figure 4.1 Urban functional hierarchy in the northern region

Source: Malaysia Urban Transport Planning Project: Ipoh Urban Transport Study [26].

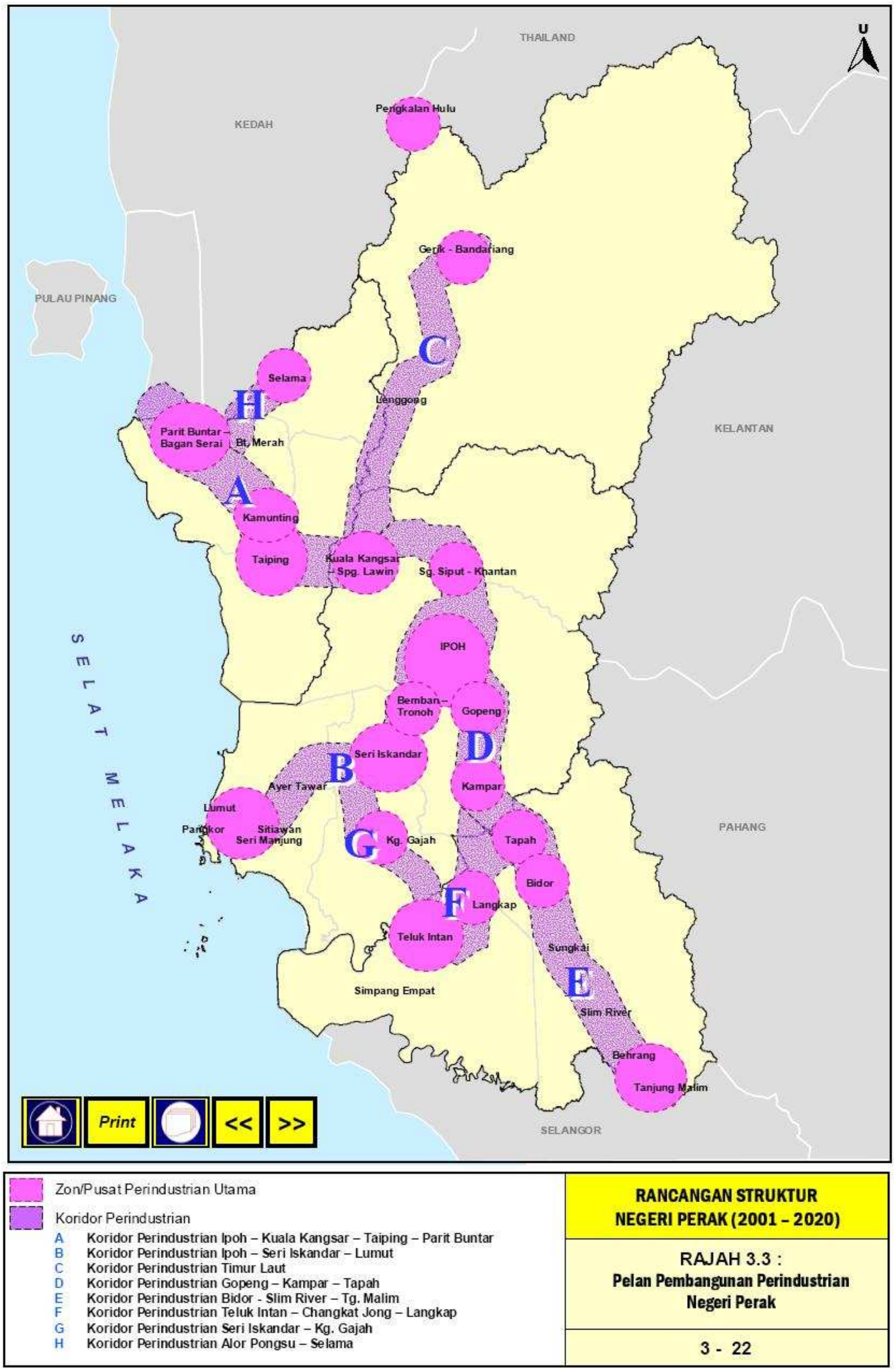


Figure 4.2 Industrial corridor (corridor B): Ipoh – Bandar Seri Iskandar – Lumut

Source: Draft of Perak's Master Plan 2020 [27]

4.1.2 Hierarchy Function and Strategic Development Centre of Perak

The hierarchy function of Ipoh which is state regional centre of Perak is categorized to stage III. In the hierarchy function (See Table 4.1), Ipoh is positioned at stage III as level as Melaka state as intermediate (connective) growth conurbation, under stage I (national growth conurbation) and stage II (regional growth conurbation). In accordance to the strategic development centre of Perak, the area of this study also play the important contribution to the entirely development of Perak State. As shown in Table 4.2, some of the strategic development centres are including corridor Seri Iskandar – Tronoh (include new urban such as Seri Iskandar, Bandar Universiti and Bemban Industrial Park) and corridor Manjung-Lumut-Sitiawan (include new urban such as Sri Manjung, Venice of Perak and Manjung Point).

Table 4.1 Hierarchy function of urban (Malay: Bandar) in RFN 2020

Stage		Bandar (Urban)	Hierarchy function
I	1.	Kuala Lumpur – Lembah Kelang – Seremban	National growth conurbation
II	1.	George Town – Kulim – Sungai Petani	Regional growth conurbation
	2.	Johor Bahru – Pasir Gudang – Tanjung Pelepas	
	3.	Kuantan - Kemaman	
III	1.	Ipoh	Intermediate (connective) growth conurbation
	2.	Melaka	
IV	1.	Temerloh – Mentakab	Future growth conurbation
	2.	Lumut – Sitiawan – Manjung	
	3.	Kota Bahru	
	4.	Kuala Terengganu	
	5.	Alor Setar	
	6.	Kangar	
	7.	Muar – Batu Pahat – Kluang	

Note: Rancangan Fizikal Negara (RFN)

Source: Draft of Perak's Master Plan 2020 [27]

Table 4.2 The strategic development centre in Perak State

No.	Corridor
i.	Ipoh-Batu Gajah Conurbation (include new urban such as Meruraya, Sunway City and Bandar Tasik Idaman)
ii.	Gopeng-Kampar (include Bandar Baru Kampar and Gopeng Industrial Park)
iii.	Taiping-Kamunting (include Bandar Baru Kamunting Raya)
iv.	Manjung-Lumut-Sitiawan (include new urban such as Sri Manjung, Venice of Perak and Manjung Point)
v.	Teluk Intan-Simpang Changkat Jong (include Bandar Baru Teluk Intan)
vi.	Seri Iskandar-Tronoh (include new urban such as Seri Iskandar, Bandar Universiti and Bemban Industrial Park)
vii.	Parit Buntar-Bagan Serai-Bukit Merah (include Bukit Merah Lake Town Resort and plan of Bandar Baru Lembah Beriah)
viii.	Tanjung Malim-Proton City-Behrang (include Bandar Baru Proton City, Proton Twin City, Behrang 2020 and Bernam Industrial Park)
ix.	Lawin-Gerik
x.	Tapah-Tapah Road (include plan of Bandar Baru Universiti)
xi.	Kuala Kangsar-Sungai Siput

Source: Draft of Perak's Master Plan 2020 [27]

4.2 Population and Economic Development

Generally, number of population and condition of socio-economic development are basic factors which drive the need of transportation development. Other factors of transportation development are explained such as availability of infrastructure, highway network, growth centre (city and region), corridor development and railway system.

4.2.1 Population growth in Perak

The population growth in some sub-regional of Perak was shown in Table 4.3 and Figure 4.3. This indicated that the increasing of the population growth in Manjung area at which Lumut located is the second top after Kinta area. During 1980 – 2002 the population in both Kinta and Manjung increased rapidly.

Table 4.3 Population growth in Perak State during 1980-2002 *)

Area	Number of population								KPPT (%)		
	1980		1991		2000		2002		1980-1991	1991-2001	2001-2002
	No	%	No	%	No	%	No	%			
Batang Padang	136,473	7.8	154,686	8.2	158,487	7.7	159,083	7.7	1.15	0.27	0.19
Manjung	143,610	8.2	168,331	9.0	198,576	9.7	199,809	9.7	1.45	1.85	0.31
Kinta	564,886	32.4	627,899	33.4	731,132	35.6	735,030	35.7	0.97	1.71	0.27
Kerian	155,765	8.9	148,720	7.9	158,830	7.7	159,430	7.7	-0.42	0.73	0.19
Kuala Kangsar	146,292	8.4	146,684	7.8	150,103	7.3	150,244	7.3	0.02	0.26	0.05
Larut Matang	223,362	12.8	235,973	12.6	248,691	12.1	249,455	12.1	0.78	0.58	0.15
Selama	26,188	1.5	35,909	1.9	35,551	1.7	35,672	1.7	1.26	-0.11	0.17
Hilir Perak	203,028	11.6	202,059	10.8	198,280	9.7	198,743	9.7	-0.04	-0.21	0.12
Hulu Perak	71,372	4.1	81,636	4.4	86,217	4.2	86,462	4.2	1.23	0.61	0.14
Perak Tengah	72,679	4.2	75,574	4.0	85,369	4.2	85,532	4.2	0.36	1.36	0.10
Total	1,743,655	100	1,877,471	100	2,051,236	100	2,059,460	100	0.67	0.99	0.20

*) Note: Report of Population in Perak State 2001
KPPT : kadar pertumbuhan purata tahunan (annual average growth rate)

Source: Draft of Master Plan of Perak 2020 [27]

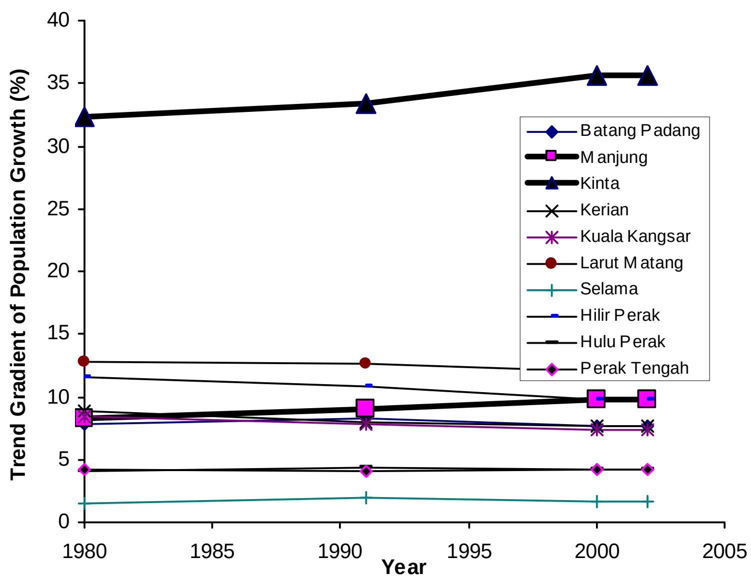


Figure 4.3 Population growth in Perak State during 1980-2002

Source: Analysis from Draft of Master Plan of Perak 2020 [27]

Perak State had population 2,023,788 people that lived in areas of 21,005 km^2 with density reaching 96 people per km^2 (See Table 4.4). From Table 4.5 we can notify, in one and two decades before, the density achieved 83 people per km^2 (1980) and 94 people per km^2 (1991). In 2007, the population achieved 2.32 million people, therefore, the density became 110 people per km^2. Thus it can be estimated that density will be more in 2010. It is clear that in decade 2000-2010 the population experience highest growth rate compare to prior decades.

As generally known, the above achievement will affect to the development of transportation, no exception for public transportation service whether in urban or in rural area. If we look into the percentage of household having motor cars/motorcycles from 1980 to 1991, than we can estimate that during one decade those number growing almost twice from 17% to 29.5% (See Table 4.5). It means that transportation by private cars will dominate the road traffic in future time.

Table 4.6 shows the population and household statistics in selected districts in accordance to Ipoh-Lumut highway corridor such as Kinta, Perak Tengah and Manjung. This corridor is an important at which Kinta and Manjung are the two top dense districts with high socio-economic activities in Perak. So that it is reasonable to priority pay attention on the transportation development in this corridor, which include three district, Kinta, Perak Tengah and Manjung. Other characteristics of the selected districts are shown in Table 4.6 to Table 4.9.

Table 4.4 Areas and population in Perak 2000

No.	District	Areas (km2)	Population (people)	Density (people/km^2)
1	Batang Padang	2,712	159,083	59
2	Hilir Perak	1,728	198,743	115
3	Hulu Perak	6,563	86,462	13
4	Kerian	958	159,430	166
5	Kinta	1,958	735,030	375
6	Kuala Kangsar	2,541	150,244	59
7	Larut, Matang & Selama	2,095	249,455	119
8	Manjung	1,171	199,809	171
9	Perak Tengah	1,279	85,532	67
	Total	21,005	2,023,788	96

Source: Profil dan Data: Perak Darul Ridzuan [53]

Table 4.5 Population and households statistics, Perak, 1980 and 1991

No.	Characteristics	1980	1991
1	Area (km^2)	21,005	21,005
2	Population size (people)	1,805,198	1,974,893
3	Population density (people per km^2)	83	94
4	Population growth: aveage annual growth rate, 1970-1980 (percent)	1.1	0.8
5	State distribution (percent)	13.3	10.7
6	Total households	333,207	398,994
7	Average household size (people)	5.2	4.6
8	Households having motorcar (percent)	17	29.5
9	Households having motorcycle (percent)	35	56.5

Source: Buku Laporan Penduduk Daerah Pentadbiran [56, 57]

Table 4.6 Population and households statistics in selected districts, Perak, 1991

No.	Characteristics	Perak	Kinta	Perak Tengah	Manjung
1	Area (km^2)	21,005	1,958	1,282	1,168
2	Population size (people)	1,974,893	627,899	75,574	168,331
3	Population density (people per km^2)	94	321	59	144
4	Population growth: aveage annual growth rate, 1980-1991 (percent)	0.8	1	0.4	1.4
5	State distribution (percent)	100	33.4	4	9
6	Total households	398,994	136,950	17,119	35,215
7	Average household size (people)	4.6	4.5	4.3	4.7
8	Households having motorcar (percent)	29.5	41.8	16.7	27.6
9	Households having motorcycle (percent)	56.5	53.1	61	66.4

Source: Buku Laporan Penduduk Negeri Perak [57]

Table 4.7 Population by selected district, Perak, 1980 and 2000

District	1980		2000	
	Population	Age 15-64	Population	Age 15-64
1. Kinta	564,500	327,730	703,493	459,793
2. Perak Tengah	73,065	39,114	82,153	47,094
3. Manjung	143,610	77,155	191,132	114,363

Source: Buku Taburan Penduduk Mengikut Kawasan Pihak Berkuasa Tempatan dan Mukim [58]

Table 4.8 Labor force and outside labor force by selected district, Perak, 1980

District	Labor force	Outside labor Force	Total
1. Kinta	118,103	124,900	243,003
2. Perak Tengah	23,883	25,968	49,851
3. Manjung	45,700	52,113	97,813

Source: Buku Taburan Penduduk Mengikut Kawasan Pihak Berkuasa Tempatan dan Mukim [58]

Table 4.9 Total population and households in selected district in Perak

District	Population (2000)	Households (2000)	Households size (1991)	Households size (2002)
1. Kinta	703,493	167,869	4.5	na
2. Perak Tengah	82,153	18,459	4.3	na
3. Manjung	191,132	43,577	4.7	4.45

Note: na : not available

Source: Buku Taburan Penduduk Mengikut Kawasan Pihak Berkuasa Tempatan dan Mukim [58]

4.2.2 Socio-economic Development

This section discusses the socio-economic characteristics between Perak State and whole country Malaysia. The selected socio-economic indicators as shown in Table 4.10 can be used to compare the position of Perak State development to the average development in the whole country, Malaysia. As known from socio-economic indicators in 2000, in term of per capita income, Perak had per capita GDP (income) RM 6,224, which only about 46% of country per capita GDP about RM 13,418. Meanwhile, the Perak's population density was not likely to be different from population density in whole country. In 2000, the population density of Perak and Malaysia is 59.5 people per km^2 and 61.8 people per km^2, respectively.

Indicator of transportation activity is generally shown by number of registered motor cars / motorcycles per 1,000 people. In 2007, Perak had 658 vehicles per 1,000 populations which were higher than those of whole Malaysia about 619 vehicles per population. This value indicated that vehicle ownership in Perak was more progressive than whole Malaysia. As shown by time series data for Malaysia during 2000-2007, the number of motor vehicles per 1,000 population increase per year in sequence is 422 (2000), 471 (2001), 490 (2002), 512 (2003), 538 (2004), 567 (2005), 593 (2006) and 619 (2007).

Table 4.10 Selected socio-economic indicators Perak 2000

No.	Indicators	Perak	Malaysia
1	Demography		
1.1	Density (per sq. km)	59.5	61.8
1.2	Urbanization	61.8	59.5
2	Economy		
2.1	GDP (1978 fixed price)	RM12,637 mil.	RM340,706 mil.
2.2	Per capita income	RM6,224	RM13,418
2.3	Primary sector contribution	21.80%	na
2.4	Secondary sector contribution	34.80%	na
2.5	Third sector contribution	57.50%	na
3	Revenues		
3.1	Poverty rate (%)	9.5	7.5
4	Health		
4.1	Population per doctor	2,497	1,455
4.2	Hospital board per 100,000 population	344	194
4.3	Birth rate	23.1	24.5
4.4	Mortality rate (per 1,000 population)	6.1	4.4
5	Education		
5.1	Students per teacher		
	- Primary school	1 : 19.6	1 : 19.8
	- Secondary school	1 : 18.4	1 : 18.7
5.2	Literacy rate (%)	95.0	93.8
6	Utilities		
6.1	Total water supplies	98.3	95.9
6.2	Total electrical supplies	99.0	97.3
7	Others		
7.1	Registered cars / motorcycles per 1,000 population	459.5	421.9
7.2	Unemployment rate (%)	2.8	3.1
7.3	Labour participation rate (%)	60.6	64.3

Source: Profil dan Data: Perak Darul Ridzuan [53]

http://www.perak.gov.my/en/modules.php?name=Content&file=print&pid=45

As shown in Table 4.11, in some selected districts at which the Ipoh-Lumut bus service corridor is located, data of income distribution is collected. This is basic information showing the revenue per month as per income category. The highest monthly income of Perak Tengah district is within range of RM 201-350, which is about 32.3%. The average income per people in Perak Tengah district is about RM 221 per month in 2005. For both Kinta and Manjung district, the income distribution data was not obtained, but those were logically estimated to have higher income than Perak Tengah district, because of the evidence that both Kinta and Manjung were categorized into urban and city with higher economic activities compare to Perak Tengah district which is most rural area with lower economic activities.

Table 4.12 shows that the increase of vehicles ownership in Perak and whole Malaysia can be indicated by increasing gross national product (GDP) per capita. The higher GDP per capita could represent the capability of people to have their own private cars. This basic assumption was used to derive the relationship between the economic growth and the motor cars (vehicles) ownership. Those results will become the indication of motorization in relation with the socio-economic development. Motorization and socio-economic relationship are discussed in the section 4.5.2.

Table 4.11 The income distribution (category) in corridor of study 2005

District	Income	Population (people)	Frequency %
Kinta	< RM 100	na	na
	RM 100 – 200	na	na
	RM 201 – 350	na	na
	RM 351 – 500	na	na
	> RM 501	na	na
	Total	na	na
Perak Tengah	< RM 100	1,865	11.5
	RM 100 – 200	4,525	27.8
	RM 201 – 350	5,250	32.3
	RM 351 – 500	3,082	18.9
	> RM 501	1,557	9.5
	Total	16,279	100
Manjung	< RM 100	na	na
	RM 100 – 200	na	na
	RM 201 – 350	na	na
	RM 351 – 500	na	na
	> RM 501	na	na
	Total	na	na

Source: Income Distribution of Perak Tengah [59]

Table 4.12 The number of vehicles per thousands people and per capita GDP

Year	Perak		Malaysia	
	Private motor cars per 1,000 population	Per capita GDP (RM)	Private motor cars per 1,000 population	Per capita GDP (RM)
1998	136.87	11,476.64	157.37	12,919.65
1999	145.26	12,314.44	167.60	13,733.58
2000	154.67	13,183.00	178.13	14,584.00
2001	161.01	14,118.99	189.81	15,400.70
2002	170.80	15,121.44	203.91	16,263.14
2003	179.20	16,195.06	216.73	17,173.88
2004	189.14	17,344.91	231.10	18,135.62
2005	200.38	18,616.00	247.75	19,189.00
2006	211.75	19,677.11	260.58	20,340.34
2007	217.37	20,798.71	273.08	21,560.76
Average	176.65	15,884.63	212.61	16,930.07
Growth rate	5.28%	6.83%	6.32%	5.86%

Source: Department of Statistics Malaysia (1998-2007) [60-62]

4.3 Infrastructure of Transportation

In this section, it was generally described about transportation development in Perak, Malaysia and it was specifically discussed about the transportation development in the area or region at which Ipoh-Lumut bus service corridor was located. The Ipoh-Lumut multiple lane highway linked Ipoh (city centre) to Lumut town (port/harbour and tourism place). The length of this highway is 82.6 km which passing within various condition of location, both rural and urban area, with various level of economic activities. The location of Ipoh-Lumut multiple lane highway is shown in Figure 4.4.

Infrastructure of transportation in Perak 2004 like as indicated in Table 4.13 is reported by UPEN Perak [53]. From this data, the length of highway of total of 8,533 km could show the domination of highway based transport against other type of infrastructure in 2004. The railway length was only 436 km (total of both single and double track). Other type of infrastructure which their existance will contribute integrally to the transportation development in Perak include runway (domestic airport), short take off landing (STOL) in Pangkor island, dry port (cargo terminal) and 480 m pier at Lumut port/harbour.

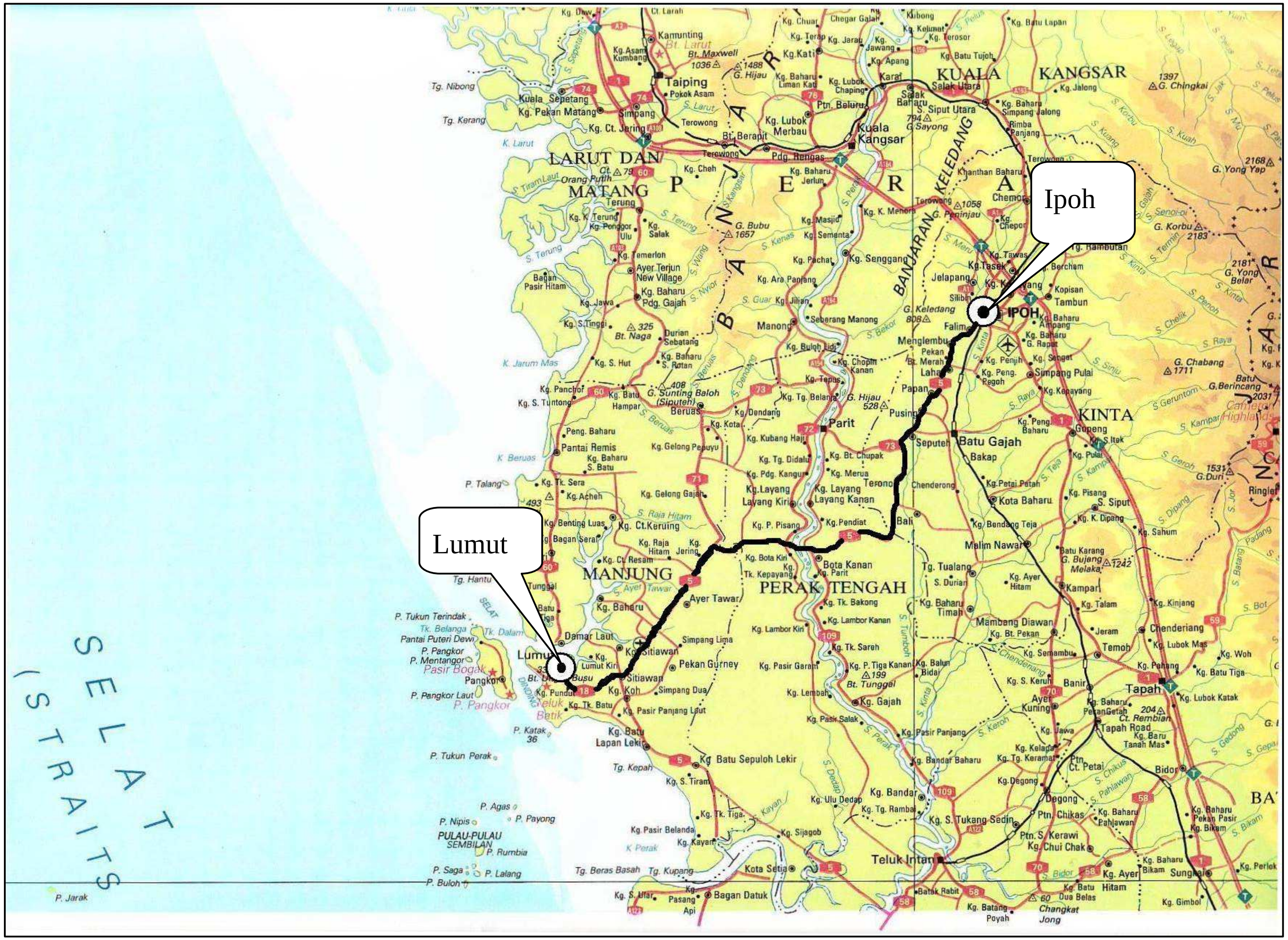


Figure 4.4 Ipoh-Lumut corridor map

Table 4.13 The selected infrastructure profile in Perak, 2004

No	Infrastructure type	Characteristics	Units
1	Lebuhraya	233	km
2	Jalan bertar	6,700	km
3	Jalan luar bandar	1,600	km
4	Landasan keretapi	262	km
5	Landasan rel berkembar	174	km
6	Lapangan terbang		
	· Ipoh	Lapangan terbang domestic	
	· Pangkor	Short take off landing (STOL)	
7	Pelabuhan darat	Ipoh cargo terminal (dry port)	
8	Pelabuhan laut	480	m (panjang dermaga)

Source: Profile dan Data: Perak Darul Ridzuan [53]

4.3.1 Highway Development

The length of Perak's road in 2005 which its growth rate of 5.1% per year was 9.1% of total road in Malaysia, less than Sabah (20.7%), Selangor (12.6%), Pahang (10%) and Johor (9.2%). In that time the growth in whole Malaysia was 3.4% per year. For instance, between 2000 and 2006, Malaysia experienced a 21% decrease in kilometers of road per 10,000 vehicles. This decrease was particularly due to higher growth rate of increase in vehicles, which grew by 7.1% per year compared to 3.4% per year for roads. Meanwhile, at Perak, there was a 6% decrease in kilometers of road per 10,000 vehicles due to the higher growth rate of increase in vehicles, which grew by 5.4% per year compared to 5.1% per year for roads.

In the Ninth Malaysia Plan 2006-2010, the indicators of road development by state in Malaysia 2005 [63], Perak has road density of 0.34 km per km^2, service rate of 3.13 km per 1,000 population and road development index of 1.03. In the whole country of Malaysia the indicators were 0.24, 2.97 and 0.85, respectively.

4.3.2 Ipoh-Lumut Highway

The Ipoh-Lumut highway will connect the developing port of Lumut with North-South Expressway (NSE) at Jelapang as a by-pass around the western side of Ipoh for longer distance traffic. It is also likely to attract a certain amount of medium distance traffic from the south-west sector of the Ipoh city. The Ipoh-Lumut highway has route starting from the northern end at Jalan Jelapang – Menglembu – Lahat – Seputeh – Tronoh – Bota – Ayer Tawar – Sitiawan and end to Lumut. At a first stage the road was constructed as a single carriageway. Currently, the road is single 4-lane standard for certain segment and divided multiple lane highway for the rest. Junctions along the route are initially expected to be high capacity at-grade signalized intersections [26]. The development issues along the Lumut – Ipoh corridor are including some aspects such as industrial corridor, hierarchy function of urban, strategic development centre and vehicles ownership trend.

4.3.3 Ipoh as City Centre

Ipoh is city centre of Perak State, situated in the mid-way of North-South Expressway connecting Kuala Lumpur and other states in the Southern Peninsular to Penang and other states in the Northern Peninsular. Kuala Lumpur is national centre whereas Penang is national regional centre. Ipoh is strategically appears to have taken on a dynamic role in the drive for regional development. Beside Ipoh is administrative functional city, Ipoh is also the centre of business district, heritage tourism city and industrial city.

4.3.4 Lumut Region as Resort Area

Lumut, the gateway to Pangkor Island, is situated about 84 km south of Ipoh City. Lumut is well known for its beautiful shell and coral handcrafts. In the Perak Tourist Information Center [64], Lumut known has strecth of beautiful beach which is a favorite haunt for campers, picnickers and sun worshippers. There are some sports like swimming and canoeing. This town is called Lumut because in the earlier days, the beach in this town is rich of moss, so the local people called it Lumut. Lumut in Malay Language is mean moss, lichen or seaweed.

There are many ways to reach Lumut, the jump off point for Pangkor. Ferry is used from Lumut to Pangkor Island. In general, the easy way to reach Lumut is taking bus, i.e. Kualalumpur – Lumut, Butterworth (Penang) – Lumut and Ipoh – Lumut.

From the comparison between several strategic places in Perak State shown that corridor Ipoh – Lumut – Pangkor have the highest of number of accommodation or hotels Table 4.14. The more number of hotels is potentially the more number of trips. It means that Ipoh – Lumut corridor is very important to be the priority of development.

Table 4.14 Number of accommodation/hotels in some corridor

No	Location	No of accommodation/ hotel
1	Ipoh-Lumut-Pangkor	83
2	Ipoh-Taiping	57
3	Taiping-Lumut	40

Sources: Analysis from the Tourism Malaysia, 2006 [64]

http://www.cuti.com.my/Sub/Perak/prk_hotel.htm

4.3.5 Railway System

In spite of the highway facility provided, the people mobility in Perak State is also served by the available of railway system which is operated by Keretapi Tanah Melayu Berhad (KTMB). There are about 12 train services passing Perak State among total of 24 services of the international railways. In fact, the existing railway system has been contributing to the growth of economic and social among states in Peninsular Malaysia. Table 4.15 contains the length of railway track in Malaysia.

Table 4.15 The length of road and railways (a)

No.	Item	2000	2001	2002	2003	2004	2005	2006
1	Total length of roads (km)	66,445	71,814	72,165	77,200	77,695	78,458	78,458 (b)
2	Length of railway track (km)	1,949	1,949	1,949	1,949	1,949	1,949	1,949
3	Number of passenger journeys by train (thousands)	3,825	3,511	3,437	3,362	3,628	3,675	3,794

Note: (a) Excludes roads maintained by Local Authorities, (b) Assumed as the same of 2005

Source: Public Works Department [65] and Department of Statistics Malaysia [60-62]

The length of railway in Perak State is about 264.7 km which spans from Tanjung Malim to Parit Buntar. Its length is about 16 percent of total length of railway system in Peninsular Malaysia of 1,667.375 km. There are main railway stations within Perak State such as Tanjung Malim, Tapah Road, Ipoh and Taiping. Beside that, there are some small railway stations, like as Slim River, Sungkai, Kampar, Batu Gajah, Sungai Siput, Kuala Kangsar, Bagan Serai and Parit Buntar.

4.4 Public Transportation (Bus Service System)

This section will emphasize on discussing on the use of buses system operation and services as an important mode in promoting public transportation. Ipoh – Lumut corridor was chosen for study case. The current bus system operation characteristics in Ipoh-Lumut corridor is served by Perak Roadways Bhd. From the observation, it has been obtained headway of 40 minute in Ipoh – Lumut direction and 46 minute in Lumut – Ipoh direction. But sometime at the operational condition, many passengers had experienced about 1 hour and more headway. The existing bus system has problem of a long waiting time for passengers getting bus. Therefore, the long waiting time is not attractive for the passengers because it is too long for getting bus. Waiting time of more than 40 minutes is very common too long. It makes the bus system is not attractive to the passengers.

The cars ownership growth as private transport is higher compared to public transportation available like bus service system. According to previous study, in whole Ipoh, bus mode only represented about 2% of the total vehicle flow [26]. In other words, the modal split indicated that the general use of local bus services in Ipoh is relatively low (2%) and this is expected to decline further if ther is no action is taken.

The land use forecasts for Ipoh indicated that commercial activity is expected to continue to rise in medium and long term. This, together with the general increase in vehicle ownership, will lead to increased demand for travel to Central Business District (CBD) from all parts of the city and beyond. Meanwhile, the increase in travel demand can not continue to be by car, because of the road space restrictions already noted. Therefore, some alternative form of public transportation must be provided.

It was important to conduct preliminary study on the existing bus service. The evaluation and assessment to improve the operation and reliability of bus journey times is necessary need for a better service and efficiency of the bus system operation. The advantages to be achieved are the public transportation service development toward efficiency of traffic, safety and environmental sustainability.

Nowadays, there are a number of current issues in public transportation operation. First, the number of population increased as well as followed by the dramatically raising of private vehicle ownership. Second, many people change for using public transportation instead of driving their own car due to the fuel price hike. Third, the number of accident is sharply increase by more than 30% within last 7 years in Malaysia (2001-2007). For example, as an illustration (See Table 4.16), daily statistic of number of users using three main types of public transportation at Klang Valley before and after restructuring fuel subsidies which influenced fuel price hike [66].

Table 4.16 Number of users by types of public transportation at Lembah Klang

Type of services	Number of users (people)		Percentage
	Before	After	(%)
1. Komuter KTM	94,000	101,000	7
2. Bas RapidKL	365,111	392,654	7.5
3. LRT RapidKL	313,753	326,095	4

Source: Berita Harian: "Hentian Bas Daif Jejas Imej Negara", 2008 [66]

4.4.1 Buses and Vehicle Mix Proportions

The main issues arising in buses service system in Ipoh are passenger/bus conflict at bus station, poorly located bus stops, poor environment of bus station, air pollution effects of aging goods vehicles and buses, conflict between buses and other traffic, circuit routing of buses, school bus operation and outdated operational procedures [26]. The types of bus distinguished in the visual appraisal included stage carriage services (local and out-station), express buses, school buses and factory buses. The vehicle mix on average consists of 59% light vehicles (cars, taxis and vans) of the traffic, 29% were motorcycles, 10% medium and heavy goods vehicles and the remaining 2% were buses of all descriptions.

4.4.2 Bicycle Transportation

How is about the role of cycling in Ipoh? Observation of movement both within and adjacent to central area (Ipoh) have indicated that cycling (in all its forms) is an important, albeit small, factor which will need to be considered. Levels of cycle usage have been observed to be far higher than in many major Malaysian cities. (e.g. Kuala

Lumpur). Trishaws have been observed to still be prevalent in the central area and are regularly used by tourist and children for journeys to and from school [26].

4.4.3 Terminal and Bus Stop

The number of public transportation passenger in Kuala Lumpur was the lowest in Asia and was due to the raising private car ownership and use. The Kuala Lumpur Structure Plan 2020 [67] revealed that public transportation covered only 20% of total Kuala Lumpur passenger transport compared to 80% for private transport.

Generally, there are two types of terminal system for transit service in Perak, main bus station (in capital of state, Ipoh) and sub terminal (in capital of district). In Capital State, Ipoh, there are Medan Gopeng bus station which mainly to facilitate inter State link and Medan Kid bus station for serving within urban (inner city) movement function. Beside Medan Gopeng and Medan Kid bus station, there are sub terminal such as sub terminal in each district, Batang Padang, Manjung, Kerian, Kuala Kangsar, Larut Matang, Hilir Perak, Hulu Perak and Perak Tengah.

The case study in Ipoh-Lumut corridor in 2006-2007, clearly indicated that the use of existing bus service as public transportation in this corridor (rural area) was quite low. It can be expressed by the low load factor of 40%. The performance service had been observed include number of passengers, frequency/headway, number of bus, operating period, operation speed, trip productivity (passengers/day, passenger-km). Based on the advance analysis, the regularity and on-time performance were quite low. The on-time performance in term of departure time less than 5 minutes was not exceeded than 25% and the service regularity (± 5 minutes) less than 30%.

4.4.4 Challenges in Public Transportation

According to Sadullah [68] and as demonstrated in [69-72] a number of aspects to consider in transportation development are summarized as follows:

1. Accessible and affordable public transportation

Government should provide accessible and affordable public transportation for all society in rural and urban. It is important to provide public transportation to support the rural and urban development. In other case, it was also the facilitation for poor society on accessibility to economic activities with reliable and affordable public transportation. This strategy is able to reduce urbanization and private car use.

2. Increasing tourist arrival to Perak need for better public transportation

   Beside tourism is necessary to provide quality human management, tourism is also necessary to offer better supporting public transportation facilities.

3. Traffic congestion and fuel consumption

   Traffic jam causes congestion and result in waste of time. Waste of time in movement can reduce the time productivity. Fuel consumption may increase along with the increasing vehicle ownership and frequently congested traffic.

4. Traffic safety is getting important

   The high rate of accident is necessary to be decreased in the future in line with transportation development. Private cars and motor cycles were the most type of vehicles involved in many accidents. The car ownership is growing faster than the supply in infrastructure and management of transportation. In transport management, the priority in promoting of public transportation can encourage people using public transportation than driving cars. The private car use may decrease and traffic accident rate may also decrease.

5. Issues on public transportation facilities

   The two main issues on public transportation use include rural public transportation and promoting public transportation for reducing the private car use. In fact, rural public transportation is less developed than urban public transportation. Increasing car ownership and fuel price hike are both the reasons people change to use public transportation and reduce private car use.

6. Encouraging public/private participation in transportation development

   There are some advantages of public/private participation in providing quality of public transportation, as follows:

   a. supporting the nation's economic growth and government in overcoming the explosive of motorization compared with growth of road length;
   b. to help the government in road construction through private investment;

c. to support the government for improvement of road traffic safety;
d. to enable the public to enjoy public transportation facilities with relatively earlier compared to if the government build these facilities itself through the government's budget allocation; and
e. to speed up the improvement of public transportation service and transit facilities, as an alternative for reducing traffic congestion, air pollution and fuel consumption.

4.5 Existing Transportation System

According to previous study by Government of Malaysia [26], number of vehicles per 1,000 population in Malaysia, especially cars and motorcycles, experienced rapid growing from 160 vehicles in 1980 to 260 vehicles in 1990 with rate of 10 vehicles per 1,000 population a year. The cars ownership was predicted gradually increasing during 1990-2020. Meanwhile, number of motorcycles was decreased as it was predicted during 2000-2020 (See Figure 4.5). Nevertheless, current fact indicates that number of motorcycles is growing than it was predicted in period 2000-2020. This prediction period is too long and may not reflect current condition as the socio-economic was change much different within 2000-2010.

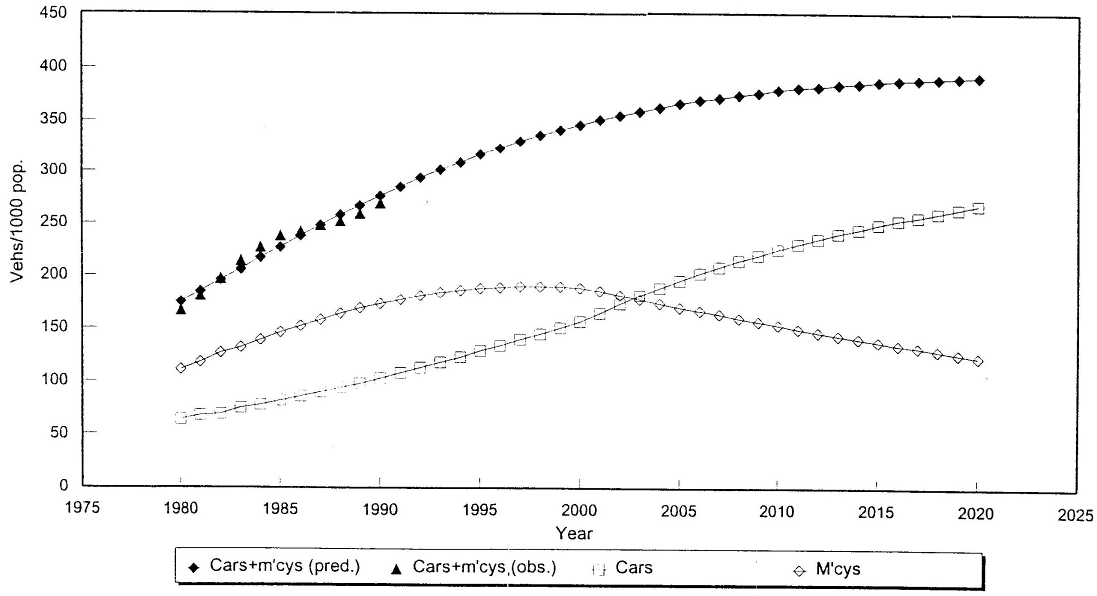


Figure 4.5 Vehicles ownership trend in Malaysia during 1980-2020
Source: Malaysia Urban Transport Planning Project: Ipoh Urban Transport Study [26]

4.5.1 Number of Vehicles (Car Ownership) in Perak

The experience from many highly-motorized countries show that road construction alone is not sufficient to solve traffic congestion in cities and that other policy measures such as high parking charges, strict enforcement of parking and traffic regulations, public transportation development and high fuel taxes are equally important. There is a general agreement among practitioners and academics that emphasis on road construction only attracts more private vehicles [71].

Malaysia's recent rapid growth in car ownership particularly in Kuala Lumpur offers evidence that rising incomes are the major driving force for car ownership. This is due to the fact that economy has grown at an average of 8.5 percent each year, making it the fast-growing economies. Car ownership was simply indicated by car-to-person ratio. In 1998, in the whole Malaysia, the car-to-person ratio of 0.2 (2 cars per 10 persons) increased to ratio of 0.3 (3 cars per 10 persons) in 2007. In Perak the car-to- person ratio of 0.1 (1998) increased to ratio of 0.2 (2007). In Kuala Lumpur, the car-to- person ratio of 0.7 (1998) increased to ratio of 1.2 (2005).

As the important state populated by 8.6% of total population in Malaysia, Perak continues to be flooded with newly-registered motor vehicles each year. The registered motor vehicles in the whole of Perak was 1,525.93 in 2007 rising from 1,078.16 (2000) by 42%, otherwise, with the annual rate of 5.1% (2000 to 2007). Table 4.17 shows the number of vehicles registered in Perak and their growth rate over period 1986-2007. The table shows the decreasing growth rates of vehicle registered during recession period 1986-1988 and after economical crisis 1997. At that time, the annual rates were less than 6.6% of whole Malaysia (1986-2007). Additionally, the average number of vehicles registered grew at an average annual rate of 5.4% during the Eight Malaysia Plan period (2001-2005) compared with 6.8% during Seventh Malaysia Plan period (1996-2000). Its annual rate was less than annual growth rate of 8.5% during Sixth Malaysia Plan period (1991-1996). It was also low rate of 4.3% during early of Ninth Malaysia Plan period (2006-2007).

The proportion of those vehicles by state, in 2005, sequentially were Kuala Lumpur (22.9), Johor (13.9), Selangor (11.9), Penang (10.7), Perak (9.5), Sarawak (6.1), Kedah (5.1), Negeri Sembilan (4.1), Pahang (4.0), Sabah (3.9), Melaka (3.4), Kelantan (3.1), Terengganu (2.2) and Perlis (0.4). And the annual rates of growth were such as 9.4, 8.4, 7.2, 8.1, 7.2, 9.3, 8.7, 8.2, 7.4, 9.8, 8.0, 8.2, 8.4 and 10.3, respectively. In whole Malaysia, the rate was 8.3.

Table 4.17 Number of vehicle (‘000s) and growth rate (1986-2007) in Perak

Year	No of vehicle	Growth rate (%)	Year	No of vehicle	Growth rate (%)
1986	400.31	-	1997	922.09	9.0
1987	417.45	4.3	1998	969.23	5.1
1988	439.17	5.2	1999	1,025.12	5.8
1989	472.06	7.5	2000	1,078.16	5.2
1990	516.62	9.4	2001	1,134.65	5.2
1991	561.45	8.7	2002	1,190.42	4.9
1992	597.55	6.4	2003	1,252.13	5.2
1993	642.57	7.5	2004	1,324.35	5.8
1994	717.53	11.7	2005	1,402.27	5.9
1995	775.75	8.1	2006	1,480.19	5.6
1996	845.69	9.0	2007	1,525.93	3.1

Source: Analysis of secondary data, Department of Statistics Malaysia [54, 60-62]

4.5.2 Motorization Indicators

Some common indicators are used to describe the motorization such as (a) private cars per 1,000 population, (b) motor cycles per 1,000 population, (c) total vehicle per 1,000 population, (d) private cars per road kilometer, (e) motorcycles per road kilometer, and (f) total vehicle per road kilometer. These indicators can be categorized in to two terms, service rate and access rate. Table 4.18 shows these indicators.

By referring to Table 4.18, in 2007, for whole Malaysia, there were total vehicle of 619 per 1,000 populations, 273 cars per 1,000 population and 292 motorcycles per 1,000 populations. In 2005, the total vehicle per 1,000 population in Perak was 621, above the average of 567 (whole Malaysia), but lower than 2,083 in Kuala Lumpur.

According to indicators of automobile dependency (Appendix D.2), in whole Malaysia, the vehicle ownership of 619 vehicles per 1,000 populations is categorized into high dependency (more than 450). Therefore, Perak with 658 vehicles per 1,000 populations is also high automobile dependency. Regarding to the service rate (vehicle per 1,000 population), in 2005, at Kuala Lumpur the number of motor car (1,250) was two times of motor cycles (613). But, in Perak the number of motor car was half of motor cycle. In Johor, Penang, Sarawak, Selangor and the whole Malaysia, the number of cars was equal to motor cycles.

Table 4.18 Vehicles per 1,000 populations and per kilometer of road (2005)

State	Population in 2005 (million)	Service rate				Length of Road in 2005 (thousand)	Access rate			
		Cars/ 1,000 pop	Motor/ 1,000 pop	Tot veh/ 1,000 pop	Bus-taxi-hired cars/ 1,000 pop		Cars/ km	Motor/ km	Tot veh/ km	Bus-taxi-hired cars/km
1. Johor	3.10	270	342	663	6.2	7.18	117	148	286	2.7
2. Kedah	1.85	103	275	407	3.5	5.50	35	92	137	1.2
3. Kelantan	1.51	106	177	305	2.6	2.84	56	94	161	1.4
4. Melaka	0.71	264	403	708	4.9	2.01	94	143	251	1.7
5. N. Sembilan	0.95	221	370	640	4.5	4.17	50	84	145	1.0
6. Pahang	1.43	153	225	412	3.2	7.79	28	41	76	0.6
7. Perak - 2004	2.23	189	365	595	3.7	7.06	60	115	188	1.2
2005	2.26	200	379	621	3.7	7.06	64	121	199	1.2
2006	2.28	212	394	648	3.7	*na*	*na*	*na*	*na*	*na*
2007	2.32	217	397	658	3.7	*na*	*na*	*na*	*na*	*na*
8. Perlis	0.22	52	190	257	1.6	0.72	16	60	81	0.5
9. Pulau Penang	1.47	431	598	1,079	5.6	2.10	302	396	755	3.9
10. Sabah	3.02	108	35	192	4.2	16.20	20	7	36	0.8
11. Sarawak	2.31	177	170	393	2.4	6.47	63	61	141	0.9
12. Selangor	4.74	167	168	371	2.3	9.82	80	81	179	1.1
13. Terengganu	1.02	105	185	315	2.0	4.52	24	42	71	0.5
14. WP. Kuala Lumpur	1.56	1,250	613	2,083	30.0	1.32	1,367	670	2,277	32.8
15. Malaysia - 2004	25.58	231	257	538	5.1	77.70	76	85	177	1.7
2005	26.13	248	268	567	5.2	78.46	83	89	189	1.7
2006	26.64	261	280	593	4.9	78.46	88	95	201	1.7
2007	27.17	273	292	619	5.0	*na*	*na*	*na*	*na*	*na*

Source: Analysis of secondary data, Department of Statistics Malaysia [54, 60-62]

In term of access rate (vehicle per kilometer), 2005, in Johor, Melaka, Perak, Penang, Selangor and Kuala Lumpur, the number of vehicles per kilometer were above the average of Malaysia (189 vehicles per kilometer). In whole Malaysia, the number of vehicles per kilometer increased by 14% during 3 years from 177 vehicles (2004) to 201 vehicles (2006).

In fact, the public transportation condition was also depicted in Table 4.18 by the number of bus, taxi and hired cars per 1,000 population (service rate) and by the number of bus, taxi and hired cars per road kilometer (access rate). In 2005, at Perak, the service rate was 3.7 and the access rate was 1.2. Those indicators were too low compared to those of Kuala Lumpur (service rate of 30.0 and access rate of 32.8).

4.5.3 Regression Analysis of Private Motor Cars

In this section, the close relationship between cars per 1,000 populaltions and the per capita income (Gross Domestic Product, GDP) in the state in whole Malaysia is examined. Table 4.19 presents both the average annual change and gross change in passenger cars per 1,000 population and per capita GDP between 1998 and 2007.

Kuala Lumpur, as a capital city, is the federal/state that has achieved the highest increase in the eight year period. However, the GDP grew with low rate. In Johor, Melaka, Penang, Sabah, Sarawak, Terengganu and Kuala Lumpur, private cars, on the average, grew more than per capita GDP.

Perak experienced the average annual growth in private cars of 5.6%, lower than the growth rate of per capita GDP (7.2%) is the highest. Meanwhile, in Kuala Lumpur which achieved highest private cars growth rate (8.4%), but lower growth of GDP (5.4%) than average of Malaysia (5.8%). For the state of Perak, this rapidly increased in GDP was due to development and the fast advancement of industries as well as the increased in housing areas and in-migrants from other states.

The number of cars per 1,000 populations is proportional to per capita GDP for all 14 states in Malaysia. The effect of per capita GDP to the increase in number of cars per 1,000 populations in Kuala Lumpur, Sabah, Sarawak and Penang, was higher than those in the whole Malaysia. Sequentially, the effect of per capita GDP which lower than the whole Malaysia was occurred in Melaka, Johor, Terengganu, Negeri Sembilan, Kedah, Selangor, Pahang, Kelantan, Perlis and Perak.

Table 4.19 Change in private motor cars per 1,000 population and GDP

No	State	Year 2005		Ave annual % change		% change (1998 - 2005)	
		Private motor cars per 1,000 population	Per capita GDP *	Private motor cars per 1,000 population	Per capita GDP *	Private motor cars per 1,000 population	Per capita GDP *
1	Johor	269.82	18,733	6.9	6.3	59.08	53.24
2	Kedah	102.58	12,132	5.8	6.5	47.87	55.39
3	Kelantan	105.62	8,638	5.6	6.8	46.40	58.14
4	Melaka	264.41	21,410	7.7	6.6	68.15	56.64
5	N. Sembilan	220.96	17,555	6.4	6.7	54.48	57.74
6	Pahang	153.08	14,549	5.9	6.9	49.69	59.12
7	**Perak**	**200.38**	**18,616**	**5.6**	**7.2**	**46.40**	**62.21**
8	Perlis	52.44	15,166	6.0	7.1	50.48	61.26
9	P. Penang	430.89	28,581	7.6	6.3	67.30	53.25
10	Sabah **	107.83	11,323	7.0	4.5	59.77	36.52
11	Sarawak	176.85	16,861	8.2	6.0	73.49	49.88
12	Selangor ***	166.62	21,286	3.5	4.1	27.07	32.80
13	Terengganu	104.82	29,516	5.7	5.6	47.68	46.38
14	**WP. Kuala Lumpur**	**1,249.97**	**39,283**	**8.4**	**5.4**	**76.25**	**44.26**
	Malaysia	**247.75**	**19,189**	**6.7**	**5.8**	**57.43**	**48.53**
	Perak - 2007			*5.3*	*6.8*		
	Malaysia - 2007			*6.3*	*5.9*		

Note: *) constant 1987 prices, **) include W.P. Labuan, ***) include W.P. Putrajaya

Source: Analysis of secondary data, Department of Statistics Malaysia [54, 60-62]

Regression analysis was performed for all states and whole country of Malaysia. Table 4.20 shows the time series data for Perak and whole Malaysia. Meanwhile, time series data for other states are not displayed. According to the model results, all parameters values were statistically significant and overall goodness-of-fit of the model was very good. In whole Malaysia, the parameter *b* represented the fixed income elasticity, which was estimated to be 1.115. It means that one percent increase in income level caused 1.115 percent increase in private cars per 1000 population. Highest value of parameter *b* was found for federal territory Kuala Lumpur (1.542) and the lowest was for Perak (0.781). Meanwhile, parameter *a* described the heterogeneous increase of motorization in the states after controlling for income growth. The highest parameter *a*, was found in Perak State (0.0926) and the lowest was in Kuala Lumpur (0.0001) (See the details in Table 4.21 and Figure 4.6).

During 1998-2007, the motorization was formulated by using non-linear equation model against per capita GDP based on the 8-year-14 states data available in Malaysia. Both models are given as:

a. $Cars\ per\ 1000\ people = 0.0926 \times (per\ capita\ GDP)^{0.7813}$: for Perak

b. $Cars\ per\ 1000 = 0.0041 \times (per\ capita\ GDP)^{1.1154}$: for Malaysia.

Table 4.20 The number of vehicles per thousands people and per capita GDP

Year	Perak		Malaysia	
	Private motor cars per 1,000 population		Private motor cars per 1,000 population	
	Cars	Per capita GDP (RM)	Cars	Per capita GDP (RM)
1998	136.87	11,476.64	157.37	12,919.65
1999	145.26	12,314.44	167.60	13,733.58
2000	154.67	13,183.00	178.13	14,584.00
2001	161.01	14,118.99	189.81	15,400.70
2002	170.80	15,121.44	203.91	16,263.14
2003	179.20	16,195.06	216.73	17,173.88
2004	189.14	17,344.91	231.10	18,135.62
2005	200.38	18,616.00	247.75	19,189.00
2006	211.75	19,677.11	260.58	20,340.34
2007	217.37	20,798.71	273.08	21,560.76
Growth rate	5.28%	6.83%	6.32%	5.86%

Source: Analysis of secondary data, Department of Statistics Malaysia [54, 60-62]

Table 4.21 The results of regression analysis of motor cars per 1,000 populations

No.	State	Parameter (b)	Coefficient of correlation, R	t-Critical = 1.89, t Stat
1	**Perak**	**0.7813**	**0.9984**	**-15.72**
2	Perlis	0.8142	0.9944	-17.00
3	Kelantan	0.8303	0.9946	-17.69
4	Pahang	0.8728	0.9987	-17.32
5	Selangor **	0.8807	0.9939	-28.41
6	Kedah	0.9021	0.9941	-18.54
7	N. Sembilan	0.9231	0.9942	-17.94
8	Terengganu	1.0361	0.9968	-21.80
9	Johor	1.1027	0.9991	-19.19
10	Melaka	1.1051	0.9968	-18.13
11	**Malaysia**	**1.1154**	**0.9967**	**-18.66**
12	P. Penang	1.2209	0.9982	-19.41
13	Sarawak	1.3626	0.9913	-20.37
14	Sabah *	1.4894	0.9261	-26.33
15	**W.P. Kuala Lumpur**	**1.5424**	**0.9990**	**-22.88**

Note: *) include W.P. Labuan, **) include W.P. Putrajaya

Source: Analysis of secondary data, Department of Statistics Malaysia [54, 60-62]

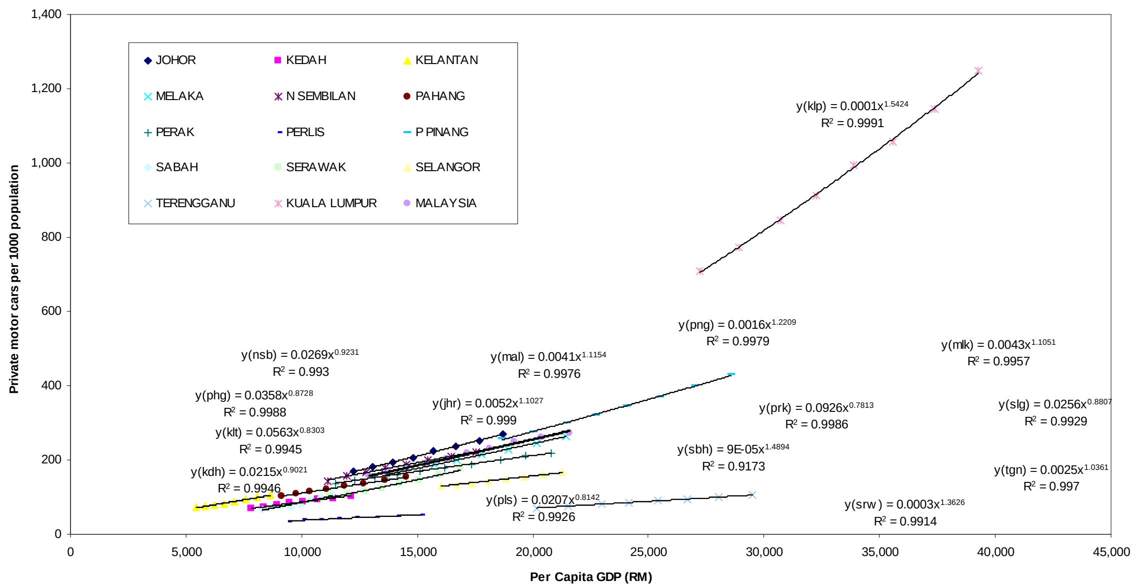


Figure 4.6 Regression of motor cars per 1,000 populations against per capita GDP

4.5.4 Road Accident as Traffic Safety Indicators

From the RTVM 2005 [28], the daily vehicular traffic at Perak from 1996-2005 are as following, 8,009 (1996), 8,242 (1997), 8,048 (1998), 8,664 (1999), 8,814 (2000), 11,225 (2001), 9,068 (2002), 10,235 (2003), 10,438 (2004) and 10,460 (2005). The daily vehicular traffic at Perak has increased by 3.5% per annual (in vehicle units) from 1996 to 2005. The characteristics of traffic in the whole of Perak in 2005 are indicated such as 24-hours volume of 20,486 vehicles, peak-hours volume of 955 vehicles per hour. The composition of traffic consisted of 47% car and taxi, 10% van and utility, 9% medium lorry, 5% heavy lorry, 2% bus and 28% motorcycle.

Traffic safety is generally described by number of accident and its fatality. The improvement in traffic safety is gained if the accident rate is decreased. Motorization had been affecting the achievement of traffic safety program. Below, there were facts about accident rate in whole Malaysia and specifically in Perak.

Hundreds of people died on Malaysian roads every year. We can see the sobering numbers especially compiled by Royal Malaysia Police, these statistics serve as a traffic safety reminder for us and all other road users. In next period, during 2000-2007, the number of accidents had increased by 45% from 250,429 to 363,319. If we see Table 4.22, in 2007, there was 31 accidents occur in 1,000 drivers. It rose compared to 31 accidents per 1,000 drivers in 2000. Clearly, it was not changed. However, the number of accident per 10,000 vehicles decreased by 8% from 236 to 216. It was due to the higher rate of growing vehicles than the driver.

Table 4.22 Road accidents facts in Malaysia 2000-2007

Year	No of accidents per 1,000 driver	Accidents index (10,000 vehicle)	Fatalities index (10,000 vehicle)	Fatalities index (100,000 population)
2000	31	236	6	26
2001	32	235	5	25
2002	32	218	5	24
2003	33	233	5	25
2004	34	237	5	24
2005	33	222	4	23
2006	33	216	4	24
2007	31	216	4	23

Source: Statistik Kemalangan Jalan Raya [73]

It was reported by JKJR [73], that by estimation in Malaysia, the total accident cost increased by 4% from RM 8,492.56 million in 2001 to RM 8,872.49 million in 2007. The serious number is about percentage of cost in death case which having 85% (RM 7,538.40 million) of total cost in 2007. The case of serious and light injuries spent cost of 13% and 2%, respectively. Other fact was decreasing fatalities index (a number of deaths in accident each 10,000 vehicles and of 100,000 population).

According to PDRM [74], the total number of accidents in Perak was 27,225 in 2005, 27,432 (2006) and 29,203 (2007). Its percentage share of accidents in the whole Malaysia was 8.3%, 8.0% and 8.0% in 2005, 2006 and 2007, respectively. From data 2007 Perak was the fifth place in number of accidents with 8.0% of total accidents in Malaysia. Above Perak there were Selangor, Kuala Lumpur, Johor and Penang with percentage share of 27.3%, 13.6%, 12.8% and 9.3%, respectively. The percentage was not exceeding 5% for other states in Malaysia. In Perak, the number of accidents changed by 7% from 27,225 (2005) to 29,203 (2007), less than in Malaysia, which changed by 11% from 328,268 (2005) to 363,319 (2007).

Table 4.23 shows the number of accidents, deaths and injuries in Perak for the years 2000-2007. In this period, the number of accidents increased with annual rate of 4%, while the number of deaths increased by 2% annually. But, both the number of serious and minor injuries decreased by 2% and 3%, respectively.

Table 4.23 Number of road accident and casualties in Perak in 2000-2007

Year	No of road accidents	No of deaths	No of serious injuries	No of minor injuries
2000	22,719	713	1,715	5,028
2001	23,700	725	1,445	5,787
2002	25,245	712	1,300	5,709
2003	25,948	739	1,403	5,296
2004	27,514	807	1,207	5,882
2005	27,225	716	1,341	4,997
2006	27,465	763	1,397	3,512
2007	29,203	811	1,426	3,734

Source: Ibu Pejabat Polis Kontinjen Perak, PDRM [75]

More specific data in 2007, for whole of Perak, a number of victims of accident were distributed by vehicle involved as following, 65% of motorcycle, 18% of car/van, 6% of pedestrian, 5% of bicycle, 4% of tractor/truck/trailer and 2% of bus. If we look into the whole Malaysia, in 2007, the highest percentage of vehicle involved in accident was car/van (68%) followed by motorcycle (16%), tractor/truck/trailer (10%), bus (2%), taxi (1%), bicycle (less than 1%) and others (2%). The fact was that the number of victims decreased annually by 1%, 5%, 5% and 1% which involved with pedestrian, motorcycle, bicycle, car and van, respectively. Those were different from other vehicles involved which increased by 11%, 3% and 3% for bus, tractor/truck/trailer and others, respectively.

4.6 Inventory of Bus Service Facilities

Important facilities of current bus service are explained such as condition of bus fleet, service schedule, ticket fares, photos documentation of bus route facilities at Ipoh-Lumut corridor. Bus route facilities include bus station, bus stop, bus stop sign board, bus bay and bus shelter.

4.6.1 Condition of Bus Fleet

Figure 4.7 shows the total mileage of existing bus fleets possessed by Perak Roadways Sdn. Bhd. plying in Ipoh-Lumut corridor highway. The detail characteristics of fleets are shown in Table 4.24. Meanwhile, the capital investment at year of vehicles registration and age of operation by 2009 is detailed in Table 4.25.

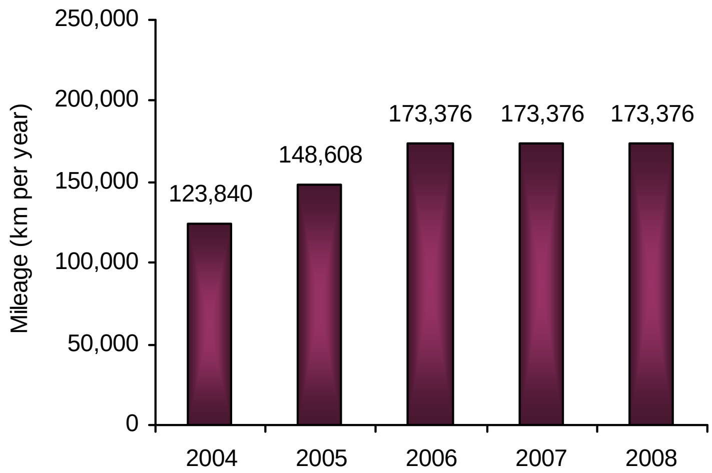


Figure 4.7 Mileage of bus fleets

Source: Perak Roadways Sdn. Bhd. [16]

Table 4.24 Number of fleets and the condition

No.	Characteristics of fleets	Description
1	Number of bus	9 fleets
2	Length of route	86 km
3	Number of trips per day	6 trips/day
4	Year of production (oldest)	1990
5	Year of production (newest)	2001
6	The age of fleets	8-19 years
7	The age of fleets operated/registered	6-19 years

Source: Perak Roadways Sdn. Bhd. [16]

Table 4.25 Number of bus and the operation age

Production	Operated/ registered	Number of bus	Capital investment (RM)	The age of operation by 2009
1990	1990	2	RM145,000	19
1991	1991	1	RM167,000	18
1993	1994	1	RM158,000	15
1994	1994	1	RM105,000	15
1995	1995	1	RM122,000	14
1996	1997	1	RM193,000	12
1997	2000	1	RM188,000	9
2001	2003	1	RM205,000	6
	Total =	9		

Source: Perak Roadways Sdn. Bhd. [16]

4.6.2 Schedule of Service

Table 4.26 shows the bus number and their operation schedule (time of departure) at the main bus station (Ipoh and Lumut). Perak Roadways Sdn. Bhd. currently operate seven 44 passenger buses from 9 available buses. Some of buses were operated for three times of departure from Ipoh, but some others were only two times of departure. The schedule of bus service is differently arranged for workdays and weekends. For the entire of year the operation hours are including (Table 4.27 and Table 4.28):

From Ipoh to Lumut: a. Monday through Thursday : 7:00 AM until 7:00 PM

b. Friday through Sunday : 7:00 AM until 7:30 PM

From Lumut to Ipoh: a. Monday through Thursday : 6:20 AM until 6:45 PM

b. Friday through Sunday : 6:20 AM until 7:50 PM

Table 4.26 Bus operation schedule (time of departure)

During 16-22 July 2007

Bus	From Ipoh				No of vehicle	Driver/crew	From Lumut
	Mon-Tue-Wed-Thu			Fri-Sat-Sun			
1	7:00 AM	11:00 AM	4:00 PM		ABR 8500	Sara/Ibrahim	
2	7:30 AM	12:00 PM	5:00 PM		ADF 8300	Sham/Jariah	
3	8:00 AM	1:00 PM	5:30 PM		AEE 5600	Anen/Sukar	7:50 PM *)
4	9:00 AM	2:00 PM			ACA 1100	Ravi/Dahalan	
5	10:00 AM	3:00 PM		7:30 PM	ABV 1800	Alex/Badio	7:30 AM
6	8:30 AM	1:30 PM	6:00 PM		ACX 600	Saari/Rahman	6:20 AM
7	9:30 AM	2:30 PM	7:00 PM		AEX 7800	Sukor(lumut)/ Kumar	7:00 AM

Source: Perak Roadways Sdn. Bhd. [16]

Table 4.26 Bus operation schedule (time of departure) - continued

During 23-29 July 2007

Bus	From Ipoh				No of vehicle	Driver/crew	From Lumut
	Mon-Tue-Wed-Thu			Fri-Sat-Sun			
1	7:00 AM	11:00 AM	4:00 PM		ADF 8300	Sham/Jariah	
2	7:30 AM	12:00 PM	5:00 PM		AEE 5600	Anen/Sukar	
3	8:00 AM	1:00 PM	5:30 PM		ACA 1100	Ravi/Dahalan	7:50 PM *)
4	9:00 AM	2:00 PM			ABR 8500	Sara/Ibrahim	
5	10:00 AM	3:00 PM		7:30 PM	ACX 600	Saari/Rahman	7:30 AM
6	8:30 AM	1:30 PM	6:00 PM		AEX 7800	Sukor(lumut)/ Kumar	6:20 AM
7	9:30 AM	2:30 PM	7:00 PM		ABV 1800	Alex/Badio	7:00 AM

Note: A driver hold the same bus (no of vehicle) in different week
maximum 6 trips per bus or 3 pairs trip (round trip)
*) Friday-Saturday-Sunday

Source: Perak Roadways Sdn. Bhd. [16]

Table 4.27 Departure time of bus from both bus stations

No.	From Ipoh	Days	From Lumut
1	7:00 AM	Monday to Thursday	6:20 AM
2	7:30 AM		7:00 AM
3	8:00 AM		7:30 AM
4	8:30 AM		8:50 AM
5	9:00 AM		9:20 AM
6	9:30 AM		9:50 AM
7	10:00 AM		10:20 AM
8	11:00 AM		10:50 AM
9	12:00 PM		11:20 AM
10	1:00 PM		12:50 PM
11	1:30 PM		1:50 PM
12	2:00 PM		2:50 PM
13	2:30 PM		1:50 PM
14	3:00 PM		2:50 PM
15	4:00 PM		3:20 PM
16	5:00 PM		3:50 PM
17	5:30 PM		4:40 PM
18	6:00 PM		5:50 PM
19	7:00 PM		6:45 PM
20	7:30 PM	(Friday/Saturday/Sunday)	7:50 PM

Source: Perak Roadways Sdn. Bhd. [16]

Table 4.28 Time table (schedule) of bus departure

Vehicle block	Leave Ipoh	Arrive Lumut	Leave Lumut	Arrive Ipoh
Shift 1				
1	7:00 AM	8:50 AM	9:00 AM	10:50 AM
2	7:30 AM	9:20 AM	9:30 AM	11:20 AM
3	8:00 AM	9:50 AM	10:00 AM	11:50 AM
4	8:30 AM	10:20 AM	10:30 AM	12:20 PM
5	9:00 AM	10:50 AM	11:00 AM	12:50 PM
6	9:30 AM	11:20 AM	11:30 AM	1:20 PM
7	10:00 AM	11:50 AM	12:00 PM	1:50 PM
Shift 2				
1	11:00 AM	12:50 PM	1:00 PM	2:50 PM
2	12:00 PM	1:50 PM	2:00 PM	3:50 PM
3	1:00 PM	2:50 PM	3:00 PM	4:50 PM
4	1:30 PM	3:20 PM	3:30 PM	5:20 PM
5	2:00 PM	3:50 PM	4:00 PM	5:50 PM
6	2:30 PM	4:20 PM	4:30 PM	6:20 PM
7	3:00 PM	4:50 PM	5:00 PM	6:50 PM
Shift 3				
1	4:00 PM	5:50 PM	6:00 PM	7:50 PM
2	5:00 PM	6:50 PM	7:00 PM	8:50 PM
3	5:30 PM	7:20 PM	7:50 PM	9:10 PM
4	6:00 PM	7:50 PM	6:20 AM	8:10 AM
5	-	-	-	-
6	7:00 PM	8:50 PM	7:00 AM	8:50 AM
7	7:30 PM	9:20 PM	7:30 AM	9:20 AM

Source: Perak Roadways Sdn. Bhd. [16]

4.6.3 Ticket Fares

All ticket fares of this bus service are based on a one way trip. In 2009, the rate of ticket varies such as full ticket fare (RM 8.40), children of 6 - 12 years (RM 4.20), children 5 years or lower (no charge - with adult) and infants (no charge - parents must provide proper car seat). Meanwhile, in 2007, the ticket fare for Ipoh to Lumut was RM 6.50 (adult) and RM 3.20 (child).

4.6.4 Bus Route Facilities

The existing bus route facilities as described by a number of documentation (photos) are shown in Figure 4.8 as the following:

1. Medan Kidd bus station
2. Perak Roadways bus pool near Medan Kidd
3. Lumut bus station
4. Platform of Perak Roadways bus at Lumut bus station
5. Bus stop sign board near by bus stop UTP
6. Bus bay and shelter in front of UTP
7. Bus bay and shelter at UTP after improvement
8. Bus shelter at UTP before improvement
9. Pedestrian crossing bridge near after bus shelter UTP
10. Bus shelter in front of UiTM street
11. Bus shelter in front of Fajar Store at Sitiawan
12. Bus shelter at Bota Kanan
13. Bus shelter in the North of Manjung bus station
14. Bus shelter in the North of Lumut bus station
15. Ticket counter at Lumut bus station
16. Bus stop sign board prior to shelter

1. Medan Kidd bus station

2. Perak Roadways bus pool near Medan Kidd

3. Lumut bus station

4. Platform of Perak Roadways bus at Lumut bus station

Figure 4.8 A number of documentation (photos) of bus route facilities

5. Bus stop sign board near by bus stop UTP

6. Bus bay and shelter in front of UTP

7. Bus bay and shelter at UTP after improvement

8. Bus shelter at UTP before improvement

9. Pedestrian crossing bridge near after bus shelter UTP

10. Bus shelter in front of UiTM street

Figure 4.8 A number of documentation (photos) of bus route facilities (Continued)

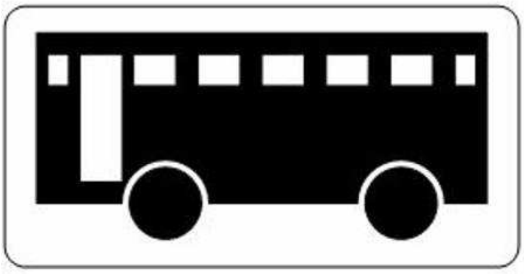
11. Bus shelter in front of Fajar Store at Sitiawan

12. Bus shelter at Bota Kanan

13. Bus shelter in the North of Manjung bus station

14. Bus shelter in the North of Lumut bus station

15. Ticket counter at Lumut bus station



16. Bus stop sign board prior to shelter

Figure 4.8 A number of documentation (photos) of bus route facilities (Continued)

4.7 Summary

Motorization is an important issue related to effort in improvement of public transportation. High motorization results negative impacts in term of congestion, noise, pollution, road accidents, wasting time, more fuel consumption and some other social impacts. The increasing motorization in whole Malaysia and also Perak insists to provide better transportation management. Therefore, it is a great opportunities to improve public transportation as an alternative to reduce above negative impacts. The public transportation improvement is able to accommodate more number of people trip rather than vehicular traffic in order to reduce private cars use. With this target, government has responsibility to setup a rule and a comprehensive regulation or policy on sustainable public transportation development to encourage more people using a public transportation service.

Generally, the motorization is really increasing throughout Malaysia and no exemption is for Perak. Perak as part of the whole Malaysia, the motorization is growing in line with increasing population and increasing income, as well as other states in Malaysia. Now, motor vehicles have become one of the transportation facilities for the Malaysian society. Every year thousands new motor vehicles are registered in this country and has increased year to year. According to indicators of automobile dependency (Appendix D.2), in whole Malaysia, the vehicle ownership of 619 vehicles per 1,000 populations is categorized into high dependency (more than 450). Meanwhile, Perak with 658 vehicles per 1,000 populations is also high automobile dependency.

The motorization has been examined by using non-linear equation model against per capita GDP. The regression model was developed by using 8-year-14 states data set in Malaysia. From the analysis obtained a fixed income elasticity (parameter b), which is 0.781 for Perak and is 1.115 for the whole Malaysia. On the other side, in the whole Malaysia and Perak the motorization will bring some negative impacts as mentioned above. Those are very important and serious challenges to public transportation development in the near future time.

The road development is important challenge to connect inter city or state in Malaysia. Road development was extremely encouraged by the fast-growth in economy. The road development then was needed to anticipate the motorization problems. The existing road will not be able to accommodate high growth of motor vehicles. The extending and widening of the road will also potentially create congestion at other points of road intersection, even many road accidents will happen. Therefore, an alternative of promoting public transportation use may be chosen to maximize people movement rather than vehicular traffic. This might be able to reduce private cars use. Government and public, together, must be encouraged to promote using of a good public transportation service.

CHAPTER 5
BUS SERVICE CHARACTERISTICS AND PERFORMANCE EVALUATION

5.0 Overview

Analysis of bus characteristics and performances evaluation was performed by using the data from the survey of boarding and alighting of passengers and data of bus operation from GPS data. The results obtained were briefly displayed and discussed in this chapter. The structure of this chapter consisted of data compiled and the analysis of bus characteristics, bus service performance, evaluation indicators, bus travel time prediction and summary of this chapter. The main bus service performances focused in the discussion included on-time performance, service regularity, punctuality index and expected average waiting time. Bus travel time prediction comes up with the method to recalculate travel time of bus operation in order to provide data for the redesigning or readjusting timetable.

5.1 Bus Service Characteristics

Bus service characteristics were obtained from the analysis of data of bus operation. Data of bus operation were collected through on-board survey. Data of time and point location when a bus stopping for passengers a long the route were recorded by using handheld GPS including such as coordinate and time. The name of point of bus stopping was recorded by entering a code of waypoint. At the same time when bus stopping the data of passengers boarding and alighting then were recorded into data sheet manually. Table 5.1 shows the results of the analysis such as vehicle capacity, route distance, route time and operating speed.

Table 5.1 Result of analysis of bus service characteristics

No.	Service characteristics	Value	Unit
1	Vehicle capacity (with no standees)	44	seats
2	Route distance (one-way)	82.6	km
3	Route time (two-way)	238	minutes
4	Operating speed	41.65	km/hour
5	Average time headway	39.66	minutes
6	Observed cycle time (CT_{obs})	258	minutes
7	Number of trips	3	trips/bus/day
8	Travel distance	660.8	km/bus/day

Table 5.2 shows that the results are very much different compared to the values of World Bank standard. It should be noted here that the standard applies particularly to city buses, which usually has a low head-way and a high service frequency. The current bus system playing in the Ipoh-Lumut corridor can not be classified into city buses, because it has a higher headway and a lower service frequency than city buses. It is right to be classified into intercity buses.

As obtained, the maximum frequency which is only 2 buses per hour is very low compared to standard (See Table 5.3). The observed headway of 26.5 to 42 minutes falls above the World Bank standard (1-12 minutes), while the travel distance in kilometer per bus per day of 660.8 is higher than the standard. The higher headway reflects the higher waiting time, thus makes the current bus system unattractive to passengers. The number of passengers (pass/bus/day) of 366 is also lower than its standard. It is reflected in a low load factor of 59% compared to normal condition of 70%. The bus availability of 100% is very satisfactory although load factor is lower.

For the other parameters such as reliability, safety, station spacing, etc., the data are unavailable at the moment. However, the reliability of bus service is discussed in section 5.2, 6.3 and 6.4. The important reliability parameters are on-time performance, punctuality, waiting time and service regularity.

Table 5.2 Bus service characteristics - World Bank standard and survey results

No.	Service characteristics (units)	World Bank standard	Survey results
1	Headway (minutes)	1-12	26.5~42
2	Travel distance (km/bus/day)	210-260	660.8
3	No. of passengers (pass/bus/day)	440-525	366
4	Load factor (%)	70	59
6	Availability (%)	80-90	100

Source: World Bank Standard and survey results

Table 5.3 Bus service characteristics - standard by Vuchic (1981) and survey results

No.	Service characteristics (Units)	World Bank standard	Survey results
1	Vehicle capacity (pass/bus)	40-120	44
2	Frequency (bus/h)	60-180	1 – 2
3	Pass. capacity of route (pass/h)	2400-8000	88 (per bus)
4	Operating speed (km/h)	15-25	41.65
5	Lane width (m)	3.00-3.65	3.75
6	Vehicle control	man/vis	man/vis
7	Reliability	low-med	na
8	Safety	med	na
9	Station spacing (m)	200-500	na

Note: man: manual, vis: visual, med: medium, na: not available

Source: Standard by Vuchic (1981) for regular bus and survey results

5.1.1 Number of Buses

Table 5.4 shows the number of buses which consist of required, available and operating number. The available and operating number of buses data was obtained from the bus operators. Required or optimum number of bus is calculated from total cycle time divided by average headway. Availability is the operating number divided by available number of bus. Ratio of bus number is ratio between operating to required numbers.

Table 5.4 Number of buses

Number of bus	Value	Unit
a. The required number (spare fleet 10%) = optimum number of buses	8	bus
b. The available number	7	bus
c. The operating number (daily)	7	bus
Availability	100	%
Ratio of bus number	0.9	-

5.1.2 Travel Time and Lost Time

The average travel time of bus operation for two-way during one week is 238 minutes (See Figure 5.1 to Figure 5.3). Table 5.5 shows that there is lost time of 18 minutes per bus because the observed cycle time (CT_{obs}) is more than calculated cycle time (CT_{cal}). Cycle time consists of route time and lay over time. Lay over time is time period to serve a variety function (change driver, administrative purposes, preparation next run, to follow the schedule, etc.). Lay over time is taken normally 10-15% of the total travel time for calculating the calculated cycle time.

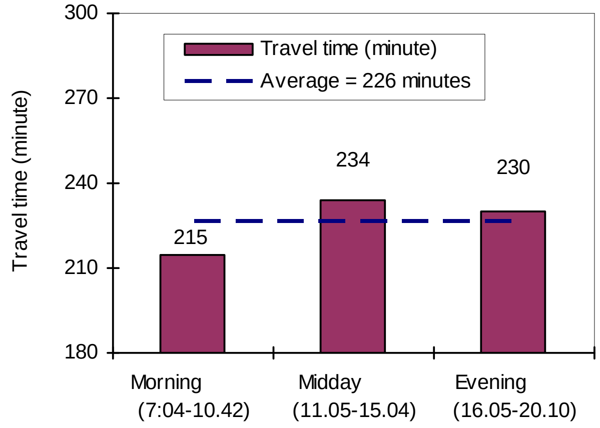


Figure 5.1 Typical of travel time during one day (round trip)

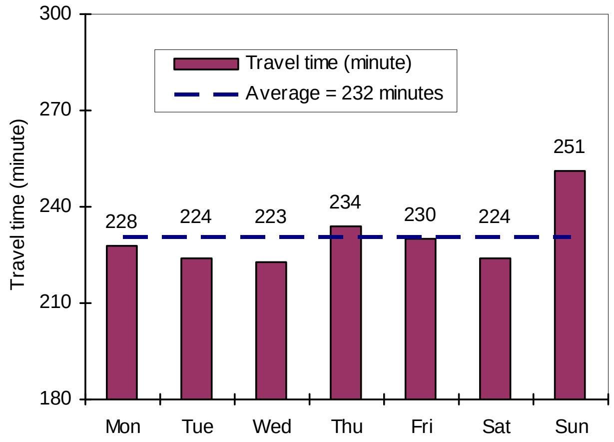


Figure 5.2 Daily travel time during one week (round trip)

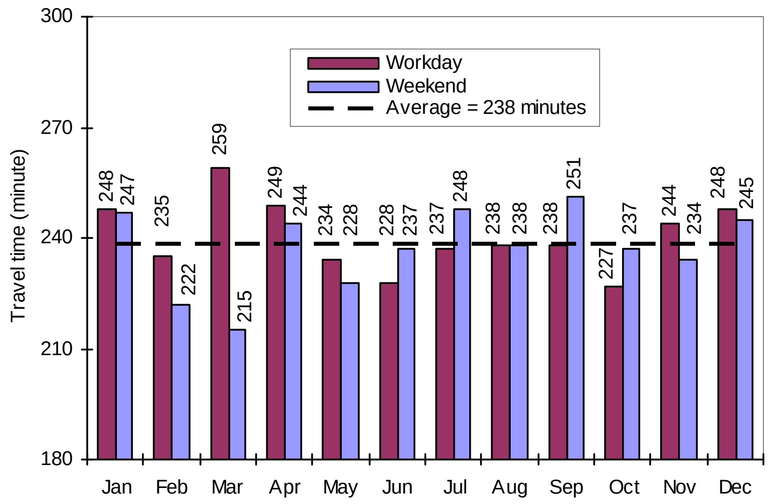


Figure 5.3 Monthly travel time during one year (round trip) 2007

For practice, calculated cycle time (CT_{cal}) is taken from the schedule (timetable), which is equal to 4 hours (240 minutes). Meanwhile, the average travel time (route time) is 238 minutes. Thus, observed cycle time (CT_{obs}) is 258 minutes (additional layover time is 10 minutes each terminal).

Table 5.5 Lost time (minute per bus)

Items	Value	Unit
CT_{cal}	240	minute
CT_{obs}	258	minute
Lost time ($CT_{obs} - CT_{cal}$)	18	minute

5.1.3 Number of Passengers and Load Factor

The result of boarding and alighting analysis shows the passengers loading profile during typical day, weekend and workday, which is presented in Figure 5.4 and Figure 5.5, respectively. It was clearly identified the number of passengers traveling along Ipoh-Lumut bus route from the preliminary survey Sunday (19 November 2006) and Tuesday (28 November 2006).

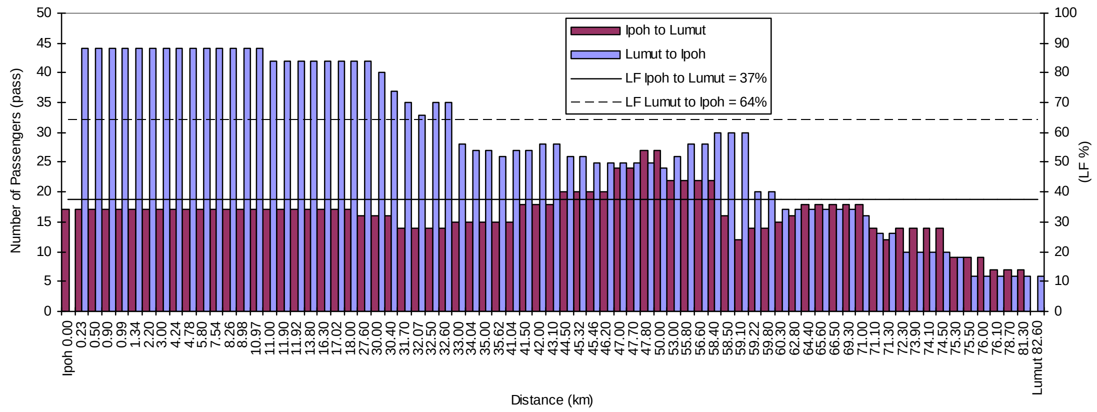


Figure 5.4 Typical boarding and alighting passengers during weekend

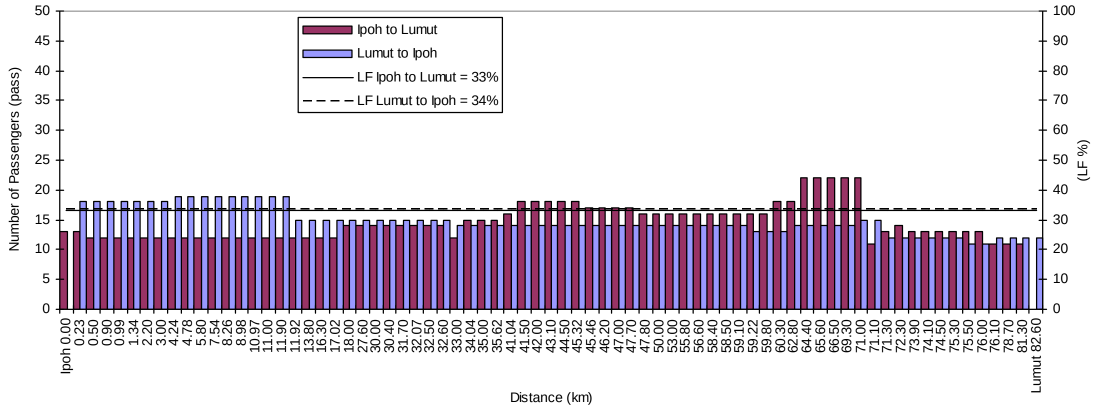


Figure 5.5 Typical boarding and alighting passengers during workday

Figure 5.6 and Figure 5.7 show the number of passengers and load factor during full one day and during one week. The load factor is high during midday period and during weekend. Table 5.8 shows the characteristics of bus operation during 12 months.

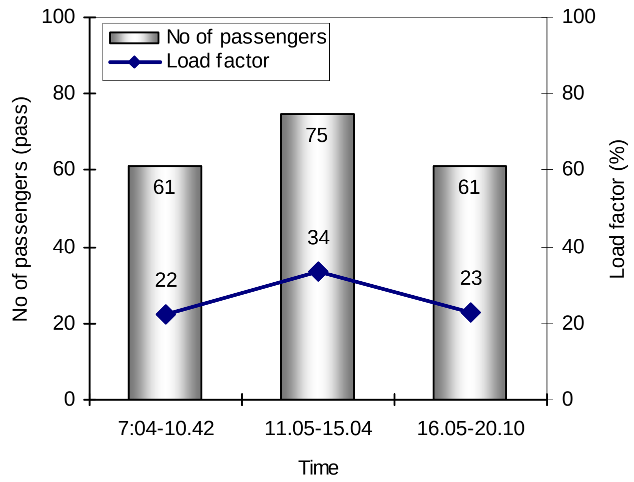


Figure 5.6 Number of passengers per bus and load factor during full one day

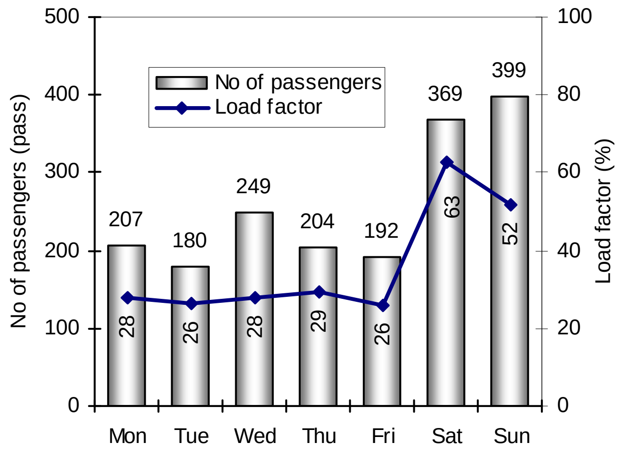


Figure 5.7 Number of passengers per bus and load factor during one week

Characteristics of bus service operation consist of one day data, one week data and one year data. Characteristics of bus service based on one day data are shown in Table 5.6. Meanwhile, for one week data and one year data, the characteristics of bus service are shown in Table 5.7 and Table 5.8, respectively. For one year data collection, in typical workday and weekend, at mid-day peak hour period (11:00 – 15:00), the bus service characteristics were recapitulated in Table 5.8. Male and female passengers were used to get bus everyday for their trip with proportion of 52% and 48% for male and female, respectively. The proportion between male and female is likely to be equal. This is clearly indicated by contingency table in Table 5.9.

Table 5.6 Characteristics of bus service (one day data, Wed, 24 Jan 2007)

Round trip	Time	Direction	Male	Female	Total	Average On bus	Average *LF* (%)	Travel time (minute)	Terminal time (minute)	Productivity (pass-km)
Trip 1	7:04 - 8:55	Ipoh to Lumut	23	20	43	11	26	111	20	799
	8:58 - 10:42	Lumut to Ipoh	9	9	18	8	19	104	3	851
		Sub Total =	32	29	61	10	22	215	23	825
Trip 2	11:05 - 12:54	Ipoh to Lumut	7	8	15	10	22	109	23	757
	12:59 - 15:04	Lumut to Ipoh	36	24	60	20	45	125	5	1,464
		Sub Total =	43	32	75	15	34	234	28	1,111
Trip 3	16:05 - 17:48	Ipoh to Lumut	14	11	25	10	23	103	61	981
	18:03 - 20:10	Lumut to Ipoh	12	24	36	10	23	127	15	577
		Sub Total =	26	35	61	10	23	230	76	779
		Average per trip	34	32	66	12	26	226	42	905
		Passengers per bus per day	101	96	197					

Table 5.7 Characteristics of bus service (one week data, 12-18 Feb 2007)

Day	Typical	Direction	Male	Female	Total	Average On bus	Average *LF* (%)	Travel time (minute)	Productivity (pass-km)
Mon	Workday	Ipoh to Lumut	66	105	171	20	45	115	4,063
		Lumut to Ipoh	15	21	36	5	11	113	1,298
		Sub Total =	81	126	207	12	28	228	2,680
Tue	Workday	Ipoh to Lumut	48	57	105	12	26	111	2,571
		Lumut to Ipoh	33	42	75	12	27	113	2,825
		Sub Total =	81	99	180	12	26	224	2,698
Wed	Workday	Ipoh to Lumut	69	75	144	13	29	111	2,813
		Lumut to Ipoh	51	54	105	12	26	112	3,239
		Sub Total =	120	129	249	12	28	223	3,026
Thu	Workday	Ipoh to Lumut	60	39	99	12	27	109	2,923
		Lumut to Ipoh	54	51	105	14	32	125	3,240
		Sub Total =	114	90	204	13	29	234	3,081
Fri	Workday	Ipoh to Lumut	57	36	93	10	22	103	2,649
		Lumut to Ipoh	51	48	99	13	30	127	3,003
		Sub Total =	108	84	192	11	26	230	2,826
Sat	Weekend	Ipoh to Lumut	69	108	177	34	77	106	7,575
		Lumut to Ipoh	57	135	192	22	49	118	6,136
		Sub Total =	126	243	369	28	63	224	6,855
Sun	Weekend	Ipoh to Lumut	132	117	249	23	53	128	5,436
		Lumut to Ipoh	96	54	150	22	51	123	5,195
		Sub Total =	228	171	399	23	52	251	5,316
	Average workday		101	106	206	12	27	227	2,862
	Average weekday		177	207	384	25	57	237	6,085
	Average		139	157	295	19	42	232	3,783

Table 5.8 Characteristics of bus service (one year data, 25 Jan to 8 Dec 2007)

Month	Number of passengers per bus per day (two ways)			Average passengers	Load factor	Passengers-kilometer per bus per day (two ways)			Travel time in minute (two ways)		
	Male	Female	Total passengers	On bus	(%)	Workday	Weekend	Average	Workday	Weekend	Average
Jan	198	218	416	27	62	5,012	7,353	6,183	248	247	247
Feb	165	182	347	26	59	4,395	8,626	6,510	235	222	228
Mar	288	206	494	35	80	8,023	9,757	8,890	259	215	237
Apr	210	245	455	27	62	5,719	8,405	7,062	249	244	246
May	132	140	272	15	35	4,275	3,225	3,750	234	228	231
Jun	198	180	378	26	60	4,747	8,670	6,708	228	237	232
Jul	176	141	317	19	44	3,392	5,574	4,483	237	248	242
Aug	119	84	203	13	30	2,362	3,821	3,091	238	238	238
Sep	159	164	323	26	60	5,535	6,660	6,097	238	251	244
Oct	129	143	272	26	60	4,886	8,096	6,491	227	237	232
Nov	224	213	437	31	71	8,334	6,668	7,501	244	234	239
Dec	272	209	480	37	84	8,922	9,301	9,112	248	245	246
Average	189	177	366	26	59	5,467	7,179	6,323	240	237	238
Workday	172	172	345	22	51						
Weekend	206	181	387	29	67		Op.speed (km/h) :		41.40	41.92	41.65

The contingency table classifies bus passengers according to type of sex and typical day (See Table 5.9). Estimated expected cell frequency is obtained by assuming the row and column classifications are independent. In an r x c contingency table, the estimated expected value of the observed cell frequency n_{ij} is equal to its respective row and column totals divided by the total frequency.

$$n_{ij} = \frac{r_i \times c_j}{n} \tag{5.1}$$

Hence, chi square value is calculated as follows:

$$\chi^2 = \sum_{i=1}^{2}\sum_{j=1}^{2}\frac{\left[n_{ij} - \hat{E}\left(n_{ij}\right)\right]^2}{\hat{E}\left(n_{ij}\right)} \tag{5.2}$$

$$\chi^2 = \frac{(172-178.2)^2}{178.2} + \frac{(172-166.4)^2}{166.4} + \frac{(206-199.8)^2}{199.8} + \frac{(181-186.6)^2}{186.6} = 0.383$$

The counts are presented in the following table.

Table 5.9 The contingency table of bus passengers' sex and typical day

Typical day	Observed			Expected		
	Male	Female	Total	Male	Female	Total
Workday	172	172	345	178.2	166.4	345
Weekend	206	181	387	199.8	186.6	387
Total	378	353	732	378	353	732

Degree of freedom calculated is df = (c-1)(r-1) = (2-1)(2-1) = 1. So for df = 1 and by assuming the significance level α = 5%. Then the critical value is $\chi^2_{5\%;1}$ = 3.84146. The value test statistics of chi square (χ^2 = 0.383) are compared to the critical value of $\chi^2_{5\%;1}$ = 3.84146. Since the test statistic of 0.383 less than the critical value, we accepted and concluded that there was not significant evidence that the proportions of the different sex types vary from typical day. In this case, the p-value of the test statistic is 0.53621.

5.1.4 Vehicle and Passenger Characteristics

For this case, the bus system is operated using 44-seat buses. Practically, in design it is assumed for some standees on bus system (for example 10% of seats), but not being considered for this analysis. The ratio between passenger and seat is 0.59. As shown in Table 5.10, the corresponding passenger loading level of service (LOS) for this bus service would be LOS B.

5.1.5 Service Frequency

For the bus system, as shown in Table 5.11, the frequencies of 1 - 2 buses per hour correspond to LOS E or D. Passenger loading LOS was used as a design standard, from which required service frequencies and bus sizes would be determined.

Table 5.10 Passengers loading LOS thresholds

LOS	Passengers per seat	Standing area per passenger (sq. ft.)	Comments
A	0.00-0.50		No passenger need sit next to another
B	0.51-0.75		Passengers can choose where to sit
C	0.76-1.00		All passengers can sit
D	1.01-1.25*	≥3.9	Comfortable standee load for urban transit
E	1.26-1.50*	2.2-3.8	Maximum schedule load for urban transit
F	>1.50*	<2.2	Crush load

Note: *Approximate values for comparison

Source: Adapted from TCRP Report 100, TCQSM 2003, [23]

Table 5.11 Service frequency LOS thresholds

LOS	Average headway (min)	Frequency (buses/hour)	Comments
A	<10	>6	Passengers do not need schedules
B	10-14	5-6	Frequent service, passengers consult schedules
C	15-20	3-4	Maximum desirable time to wait if bus missed
D	21-30	2	Service unattractive to choice riders
E	31-60	1	Service available during the hour
F	>60	<1	Service unattractive to all riders

Source: TCRP Report 100, TCQSM 2003, [23]

5.2 Bus Service Performance

A number of bus service performances proposed are evaluated to assess the current bus service operation such as on-time performance, service regularity, punctuality index and expected average waiting time. This performance indicator can describe the reliability of bus service based on scheduled and actual travel time or departure time.

5.2.1 On-Time Performance

It was assumed to be approximately 10% of scheduled interval (60 minutes) after departure time for determination of whether a bus departure is on-time or late [29]. Hence, the accepted interval for on-time departure is within 0-5 minute interval.

Figure 5.8 indicated that there was a difference of on-time performance at bus stops between Lumut to Ipoh and Ipoh to Lumut directions. As on-time performance of 0-5 minutes after departure time is considered, there were 13% of total trips from Ipoh to Lumut and 9% of total trips from Lumut to Ipoh. The ideal on-time performance is 100%, where higher percentage indicates better performance of bus service. See also Table 5.12 for detail description. The comparison of on-time performance between main bus stations and bus stops were also displayed in Figure 5.9. On-time performance at main bus stations was better than of that at bus stops. That is because of there was layover/recovery time available at main bus station for starting and ending of trips.

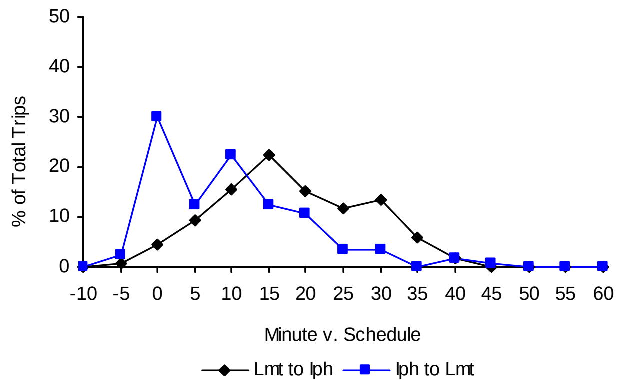


Figure 5.8 On-time performance distribution at bus stop

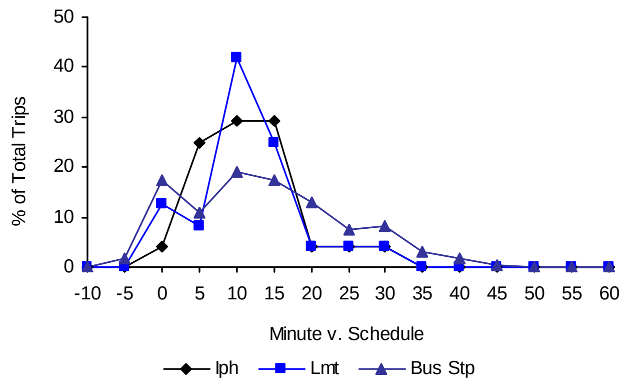


Figure 5.9 On-time performance distribution at bus station and bus stop

Table 5.12 Cumulative distribution of total trips based on departure time

Station	Minute versus schedule								
	< -5	-5-0	0-5	0-10	0-15	0-20	0-25	0-30	>30
Bus Station									
Ipoh	0	4	25	54	83	88	92	96	0
Lumut	0	13	8	50	75	79	83	88	0
Bus Stop									
Ipoh to Lumut	3	30	13	35	48	58	62	65	3
Lumut to Ipoh	1	4	9	25	47	62	74	87	8
Average	2	17	11	30	47	60	68	76	5

5.2.2 Service Regularity

Monthly distribution of service regularity had not indicated any specific state yet, as there was not monitored annually (See Table 5.13). Table 5.14 showed the distribution of regularity at each station. The total percentage of passing as indicator of regularity falls into low percentage. The regularity at Ipoh bus station, Lumut bus station and all bus stops were 29.2%, 20.8% and 31.3%, respectively. All regularity values were relatively around 30% which they were at the same route.

Table 5.15 tabulated the summary of early, on-time and late in terms of percentage of total trips, meanwhile the service regularity was percentage of actual interval passing to total scheduled interval.

Table 5.13 Monthly distribution of regularity

Regularity	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
% Fail	100.0	79.2	66.7	41.7	75.0	79.2	45.8	45.8	95.8	52.3	86.4	87.5
% Pass	0.0	20.8	33.3	58.3	25.0	20.8	54.2	54.2	4.2	47.7	13.6	12.5

Table 5.14 Distribution of regularity each station

Station	% of Fail			% of Pass		
	Workday	Weekend	Total	Workday	Weekend	Total
Bus stop (average)						
TmMj	39.6	33.3	72.9	60.4	66.7	27.1
BtKa	37.5	33.3	70.8	62.5	66.7	29.2
AyTw	33.3	37.5	70.8	66.7	62.5	29.2
Stwn	27.1	33.3	60.4	72.9	66.7	39.6
MjBs	33.3	35.4	68.8	66.7	64.6	31.3
Main bus station and bus stop						
Ipoh bus sta	41.7	29.2	70.8	58.3	70.8	29.2
Lumut bus sta	37.5	41.7	79.2	62.5	58.3	20.8
Bus stop	34.2	34.6	68.8	65.8	65.4	31.3

Table 5.15 Early, on-time, late and regularity

Station	Early	Early	On-time	Late	Regularity
	< -5 min	-5-0 min	0-5	>5	± 5 minute
Ipoh bus sta	0	4	25	71	29.2
Lumut bus sta	0	13	8	79	20.8
Bus Stop	2	17	11	70	31.3

5.2.3 Punctuality Index and Expected Average Waiting Time

Punctuality indexes of a bus stop or a bus station for a bus route also indicate the reliability of bus service. This index is indicating the magnitude of time gap between actual arrival time and scheduled arrival time (headway adherence) [34]. The punctuality is a statistically representative index to indicate the variation against the average. The expected average waiting time by considering the punctuality index is

$$E\{w\} = \frac{1}{2}\bar{h}\left(1 + P_I\right) \tag{5.3}$$

where, P_I is punctuality index.

The longer headway adherence will indicate the lower punctuality index. Based on the punctuality index and refer to standard in Table 5.16, it is shown that the bus system service reliability in average correspond to LOS E (See Table 5.17).

Both of punctuality index (P_I) and expected average waiting time ($E(w)$) are not significantly different according to typical day between workday and weekend. This is shown by the value of t-Statistical which is less than t-Critical one-tail (Table 5.18).

Table 5.16 The fixed-route headway adherence LOS

LOS	C_{vh}	$P(\|h_i\text{-}h\|>0.5h)$	$(1+P)$	Comments
A	0.00-0.21	1%	<1.04	Service provided like clockwork
B	0.22-0.30	10%	1.05-1.09	Vehicles slightly off headway
C	0.31-0.39	20%	1.10-1.15	Vehicles often off headway
D	0.40-0.52	33%	1.16-1.27	Irregular headways, with some bunching
E	0.53-0.74	50%	1.28-1.55	Frequently bunching
F	>0.75	>50%	>1.55	Most vehicles bunched

Source: TCRP Report 100: TCQSM 2003, [23]

Table 5.17 Punctuality index and expected average waiting time each station

Stop (station)	Bus station / bus stop	Scheduled headway (minute)	Punctuality Indexes (P_I)		Expected Average Waiting Time ($E(w)$) in minute		LOS upon P_I
			workday	weekend	workday	weekend	
1	Bus stop (Bota Kanan)	30	0.27	0.30	19.0	19.5	D
		60	0.07	0.08	32.0	32.3	B
2	Ipoh (bus station)	30	0.57	0.61	23.6	24.2	E
		60	0.14	0.15	34.3	34.6	C
3	Lumut (bus station)	30	0.44	0.56	21.6	23.4	E
		60	0.11	0.14	33.3	34.2	C
	Average		0.29	(ρ = 71%)	27.67		E
	Minimum		0.07	(ρ = 93%)	19.00		B
	Maximum		0.61	(ρ = 39%)	34.60		F

Table 5.18 T-test for punctuality and waiting time

	Punctuality Index (P_I)				Expected Average Waiting Time ($E(w)$)		
	workday	weekend			workday	weekend	
Mean	0.266667	0.306667		Mean	27.3	28.03333	
Variance	0.040267	0.051987		Variance	44.432	41.66667	
Observations	6	6		Observations	6	6	
Pearson Correlation	0.989809			Pearson Correlation	0.996767		
Hypothesized Mean Difference	0			Hypothesized Mean Difference	0		
df	5			df	5		
t Stat	**-2.390457**	*)		t Stat	**-3.16228**	*)	
P(T<=t) one-tail	0.031176			P(T<=t) one-tail	0.012516		
t Critical one-tail	**2.015048**			t Critical one-tail	**2.015048**		
P(T<=t) two-tail	0.062352			P(T<=t) two-tail	0.025031		
t Critical two-tail	2.570582			t Critical two-tail	2.570582		

Note: *) T-test (paired two samples for means)

Figure 5.10 to Figure 5.12 show the cumulative frequency of headway adherence for overall bus stop, at Ipoh bus station and at Lumut bus station, respectively. Headway adherence at overall bus stop has the highest frequency of 23% at headway adherence of 5 minutes. At Ipoh bus station the highest frequency is 30% at headway adherence of 25 minutes. Meanwhile, at Lumut bus station, the highest frequency is 22% at headway adherence of 10 minutes.

Figure 5.13 to Figure 5.15 show cumulative frequency of headway adherence by typical day for overall bus stop, at Ipoh bus station and at Lumut bus station, respectively. In overall bus stop, cumulative frequency of headway adherence is relatively same for both workday and weekend. However, cumulative frequency of headway adherence at Ipoh bus station during weekend is higher than during workday. This is different pattern of cumulative frequency of headway between Ipoh and Lumut bus station.

Figure 5.16 and Figure 5.17 show the characteristic of headway adherence at bus stop and bus station upon the direction Ipoh to Lumut and Lumut to Ipoh, respectively. In both directions, the cumulative frequency of headway adherence at bus stop is higher than at bus station.

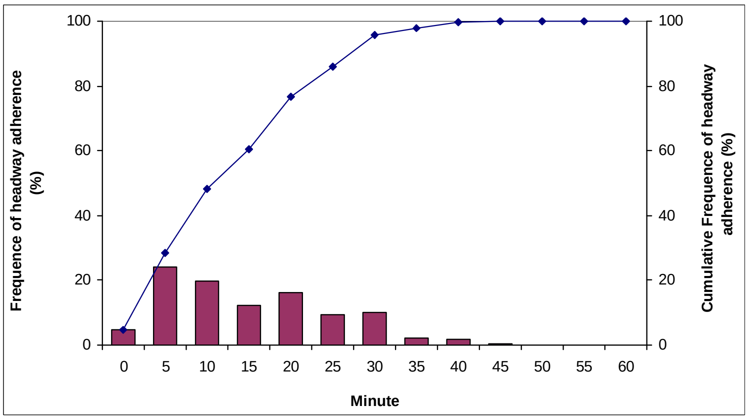


Figure 5.10 Cumulative frequency of headway adherence for overall bus stop

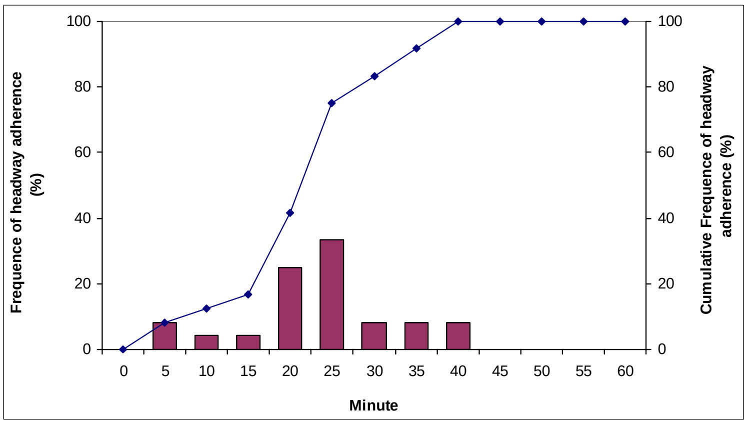


Figure 5.11 Cumulative frequency of headway adherence at Ipoh bus station

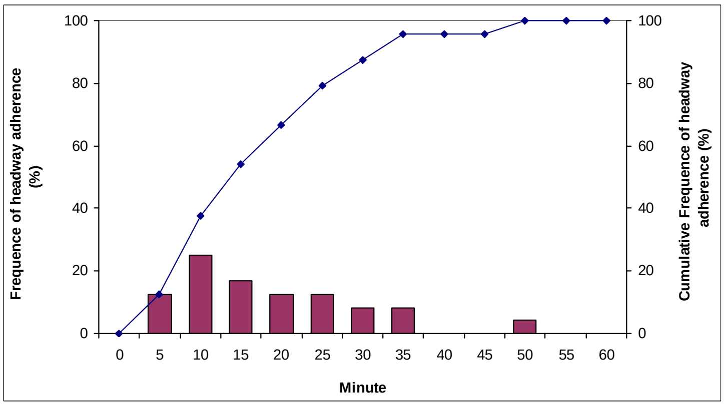


Figure 5.12 Cumulative frequency of headway adherence at Lumut bus station

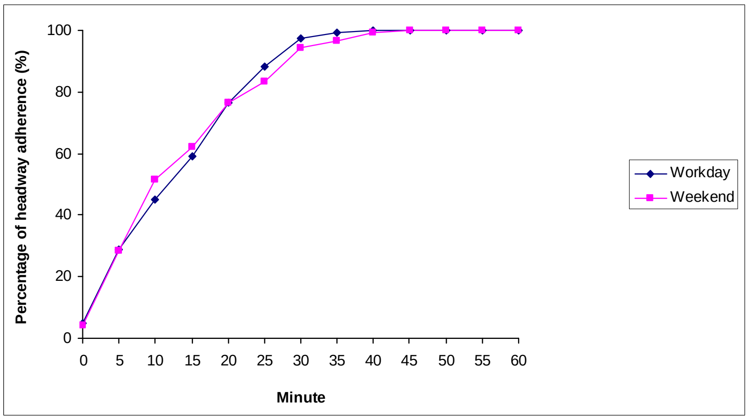


Figure 5.13 Cumulative frequency of headway adherence for overall bus stop by typical day

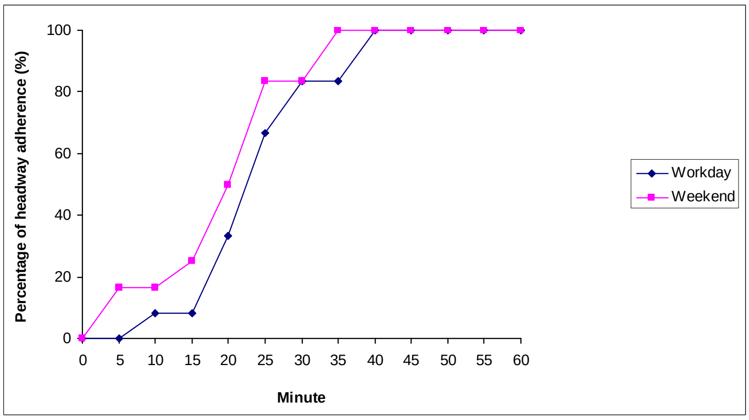


Figure 5.14 Cumulative frequency of headway adherence at Ipoh bus station by typical day

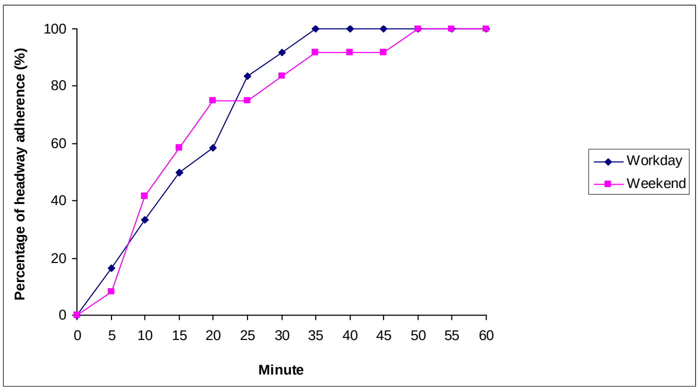


Figure 5.15 Cumulative frequency of headway adherence at Lumut bus station by typical day

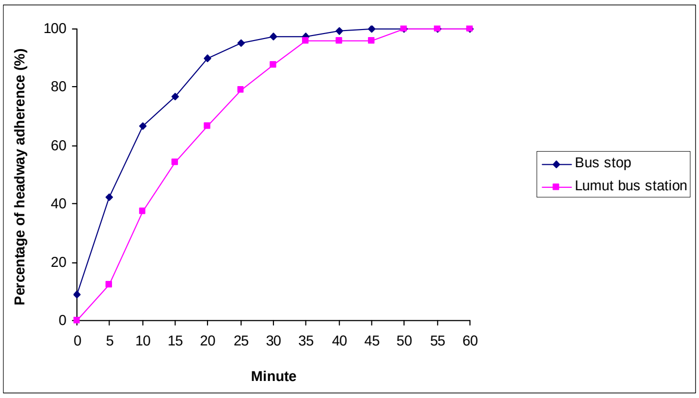


Figure 5.16 Frequency of headway adherence for overall bus stop, Ipoh to Lumut

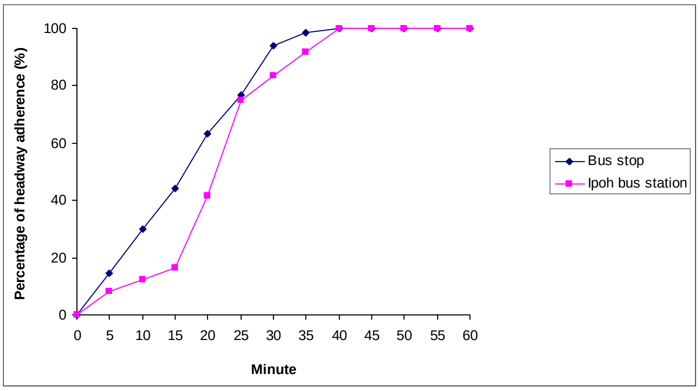


Figure 5.17 Frequency of headway adherence for overall bus stop, Lumut to Ipoh

5.3 Bus Travel Time Prediction

In this section, three models are used for bus travel time prediction, including autoregressive integrated moving average (ARIMA) model, partial least square (PLS)

- multiple linear regressions (MLR) and statistica neural network (SNN) model. The results are explained briefly below.

5.3.1 ARIMA Model

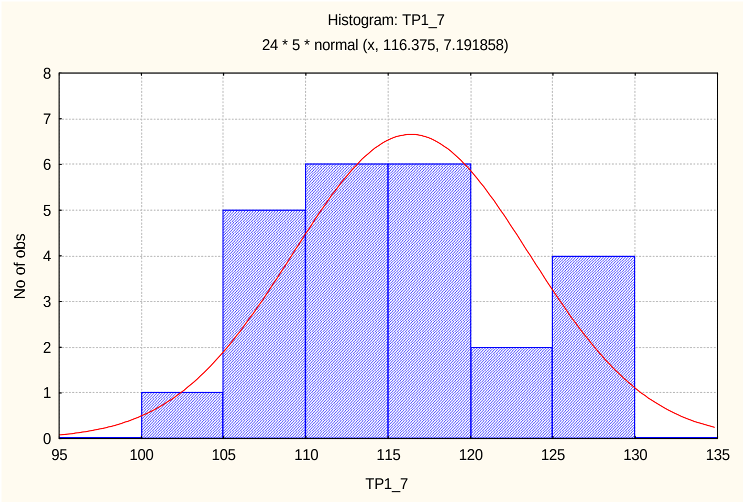
ARIMA model is chosen due to the simple use for time series data analysis and the pattern of data is fluctuated in time basis. Suwardo modeled bus travel time prediction by applying ARIMA model based on the travel time series data.

5.3.1.1 Graphical data presentation

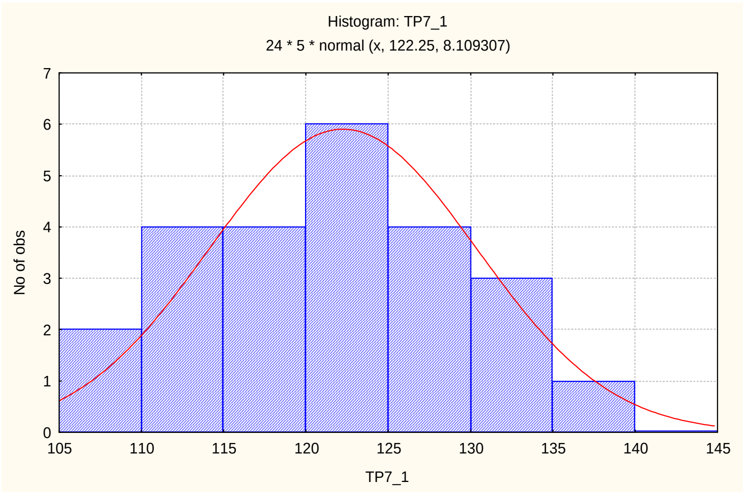
Data for analysis were series data of bus travel time collected from January to December 2007. Observation was done for two typical days, workday and weekend each month. The unit of travel time is measured in minute, thus, unit of minute is consistently used in the discussion. Descriptive statistics of bus travel time series was summarized in Table 5.19. From the Figure 5.18, it was shown that the distribution of travel time met with normal distribution N(x, 116.38, 7.192) for Ipoh to Lumut direction (from time point TP=1 to time point TP=7). Meanwhile, for the opposite direction, Lumut to Ipoh, the normal distribution fitting was N(x, 122.25, 8.109). The difference of average travel time of both directions is 5.9 minutes (5% difference). This is due to the operating speed for Lumut to Ipoh direction is lower (40 km/h) with the higher variation of travel time (6.6%) compared to those of Ipoh to Lumut direction. For Ipoh to Lumut direction, the operating speed and variation of travel time are 43 km/h and 6.1%, respectively.

Table 5.19 Descriptive statistics of bus travel time

	TP1_7 : Travel time from TP=1 to TP=7	TP7_1 : Travel time from TP=7 to TP=1
Mean	116.375	122.25
Std.Dv.	7.191858	8.109308
Minimum	102	110
Maximum	129	139
First	1	1
Last	24	24
N	24	24



(a) From Ipoh (TP=1) to Lumut (TP=7)



(b) From Lumut (TP=7) to Ipoh (TP=1)

Figure 5.18 Histogram and normal distribution of bus travel time

Based on the Box & Whisker Plot Figure 5.19, for both directions, the standard deviation and standard error of travel time changed increasing as the distance traveled increased from the starting time point to the downstream time points. The standard deviation plot, for instance, between time points of 1_2, 1_3, 1_4, 1_5, 1_6 and 1_7 tended to increase because there was delay propagation due to various traffic conditions and bus operating speed. The same changes were experienced for other pairs of time points.

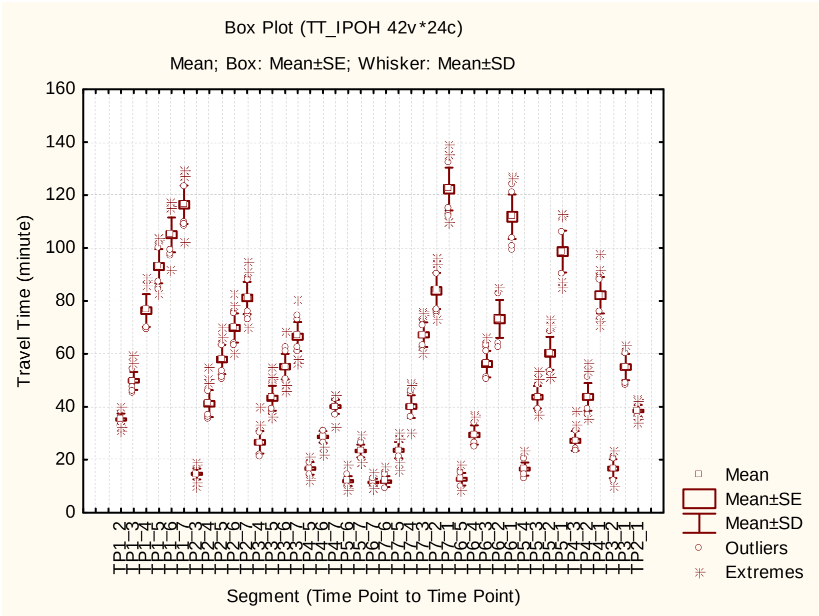


Figure 5.19 Standard deviation and standard error of bus travel time

5.3.1.2 The art of ARIMA model building and forecasting

By following of the steps in the models-building, the results can be obtained, as shown in Figure 5.20 to Figure 5.22. The time series data are considered to be stationary at around the mean value. Most of the autocorrelation values are smaller than 1.96 times their standard errors (i.e., the probability of 95% confidence limit) as indicated by the dotted line in the autocorrelation function (ACF) plot in Figure 5.21 and Figure 5.22. The time series is stationary because the graph of ACF of the time series values either cuts off fairly quickly or dies down fairly quickly. Thus, it was not necessary to make transformation and differencing of the data, in this case d=0. To build the proper model, it was reasonable to apply some tentative ARIMA models for Ipoh to Lumut direction such as ARIMA(0,0,1), ARIMA(0,0,2), ARIMA(1,0,0) and ARIMA(2,0,0). And, for the Lumut to Ipoh direction, the tentative models considered were as follows: ARIMA(0,0,1), ARIMA(0,0,2), ARIMA(1,0,0) and ARIMA(2,0,0).

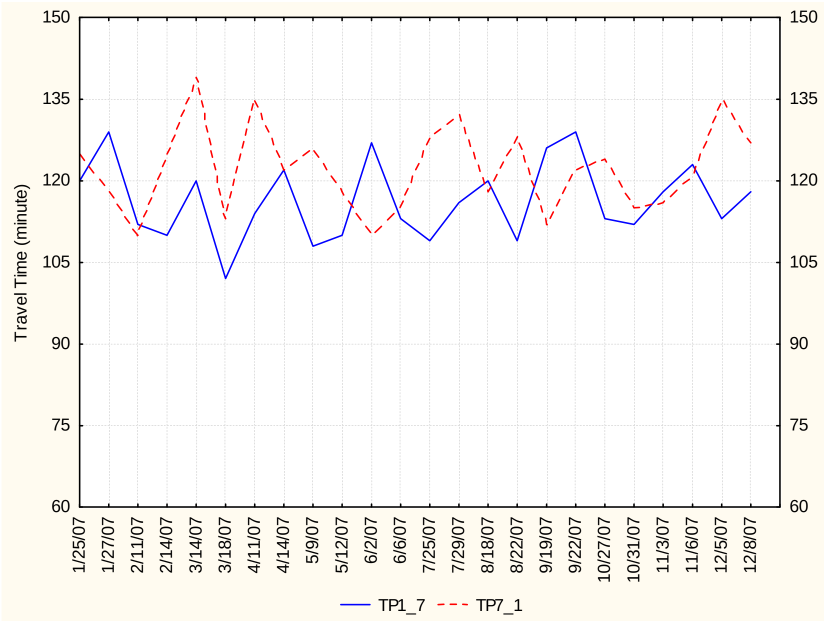


Figure 5.20 Time series plot of the bus travel time

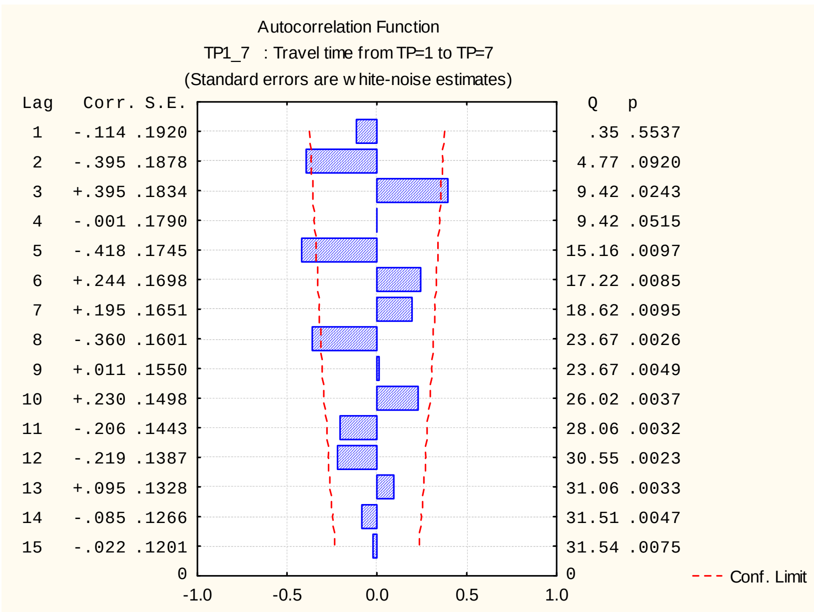


Figure 5.21 ACF of the bus travel time

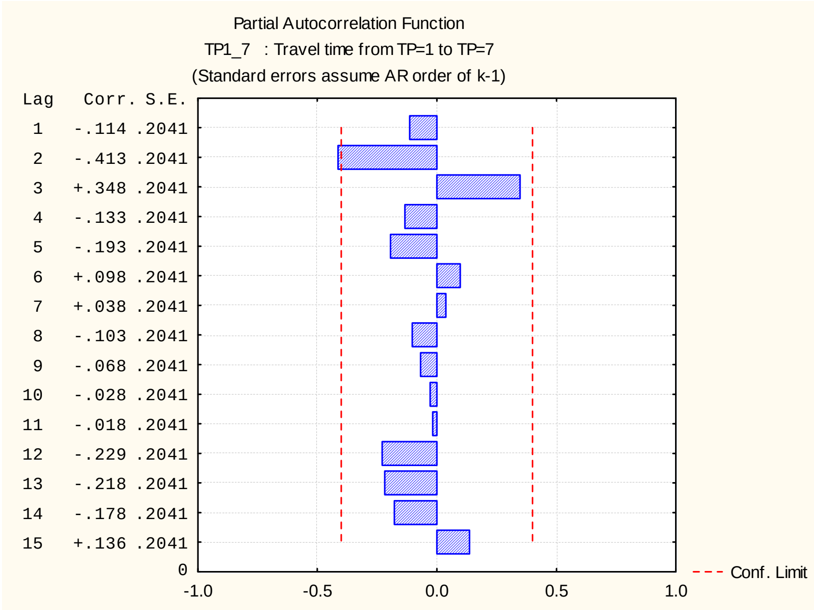


Figure 5.22 PACF of the bus travel time

Table 5.20 indicates the estimated parameters of selected model of bus travel time prediction. Parameter estimation in ARIMA models is completely achieved by maximizing the likelihood (probability) of the data. The method for computing maximum likelihood value is Exact (Melard). For Ipoh to Lumut direction (from TP=1 to TP=7), the model was without transformation (the amount of difference, d=0), named ARIMA(0,0,2) = MA(2) with MS Residual = 46.722. Furthermore, the model for Lumut to Ipoh direction (from TP=7 to TP=1) is ARIMA(0,0,1) = MA(1) with MS Residual = 68.102.

Table 5.20 Estimated model parameters for bus travel time

Input: TP1_7 : Travel time from TP=1 to TP=7 (ARIMA_TT)
Transformations: none
Model:(0,0,2) MS Residual= 46.722

	Param.	Asympt. Std.Err.	Asympt. t(21)	p	Lower 95% Conf	Upper 95% Conf
Constant	116.1627	0.9341	124.3513	0.0000	114.2200	118.1053
q(1)	-0.0447	0.2039	-0.2191	0.8287	-0.4687	0.3794
q(2)	0.4289	0.1885	2.2757	0.0335	0.0370	0.8208

Input: TP7_1 : Travel time from TP=7 to TP=1 (ARIMA_TT)
Transformations: none
Model:(0,0,1) MS Residual= 68.102

	Param.	Asympt. Std.Err.	Asympt. t(22)	p	Lower 95% Conf	Upper 95% Conf
Constant	122.2072	1.5267	80.0476	0.0000	119.0411	125.3734
q(1)	0.1218	0.2855	0.4266	0.6738	-0.4703	0.7139

More details, all the tentative ARIMA models were shown below. Based on the estimated model parameters of respective bus travel time resulted by using STATISTICA 7 software [76], it could be obtained the models in the form as the following in Table 5.21.

From Figure 5.23 to Figure 5.25, it is revealed that the selected ARIMA(0,0,2) or MA(2) is an appropriate model for bus travel time at Ipoh to Lumut direction and is better than other tentative ARIMA models. Similarly, by using the other graph for Lumut to Ipoh direction it can be obtained the ARIMA(0,0,1) or MA(1) which is proper model for bus travel time in the case.

The models were checked for adequacy by considering the properties of the residuals whether the residuals from an ARIMA model has the normal distribution and should be random. For overall, as shown in Figure 5.24, the models are considered adequate as the p-value of associated with the Ljung-Box Q statistic is large (p-value > α). The equation of the final result can be used to approximately generate the historical patterns of bus travel time in a time series and forecast the future value of the time series of bus travel time.

Table 5.21 Model results of bus travel time

Models	Equations	Note
1. Ipoh to Lumut direction:		
a) ARIMA(0,0,1) = MA(1)	$Y_t = 116.2890 - 0.2602*\varepsilon_{t-1}$	1st order moving average
b) ARIMA(0,0,2) = MA(2)	$Y_t = 116.1627 + 0.0447*\varepsilon_{t-1} - 0.4289*\varepsilon_{t-2}$	2nd order moving average
c) ARIMA(1,0,0) = AR(1)	$Y_t = 116.3530 - 0.1107*Y_{t-1}$	1st order autoregressive
d) ARIMA(2,0,0) = AR(2)	$Y_t = 116.1699 - 0.1828*Y_{t-1} - 0.4606*Y_{t-2}$	2nd order autoregressive
2. Lumut to Ipoh direction:		
a) ARIMA(0,0,1) = MA(1)	$Y_t = 122.2072 - 0.1218*\varepsilon_{t-1}$	1st order moving average
b) ARIMA(0,0,2) = MA(2)	$Y_t = 121.9329 - 0.5090*\varepsilon_{t-1} - 0.4910*\varepsilon_{t-2}$	2nd order moving average
c) ARIMA(1,0,0) = AR(1)	$Y_t = 122.2269 - 0.0794*Y_{t-1}$	1st order autoregressive
d) ARIMA(2,0,0) = AR(2)	$Y_t = 122.1416 - 0.0979*Y_{t-1} - 0.1519*Y_{t-2}$	2nd order autoregressive

From Figure 5.23 , the histogram shows that it looks like the residuals are normally distributed. Apparently, it seems how well the normal distribution fits the actual distribution of residuals. Moreover, it can be checked the properties (randomness) of the residuals with the graph of ACF and PACF (partial autocorrelation function) of the residual (See Figure 5.24 and Figure 5.25). The individual residual autocorrelation was small and generally falling within limit ±

1.96/√N of zero (there is no residual serial correlation). In other words, the residuals are independent of each other as second criteria of ARIMA models.

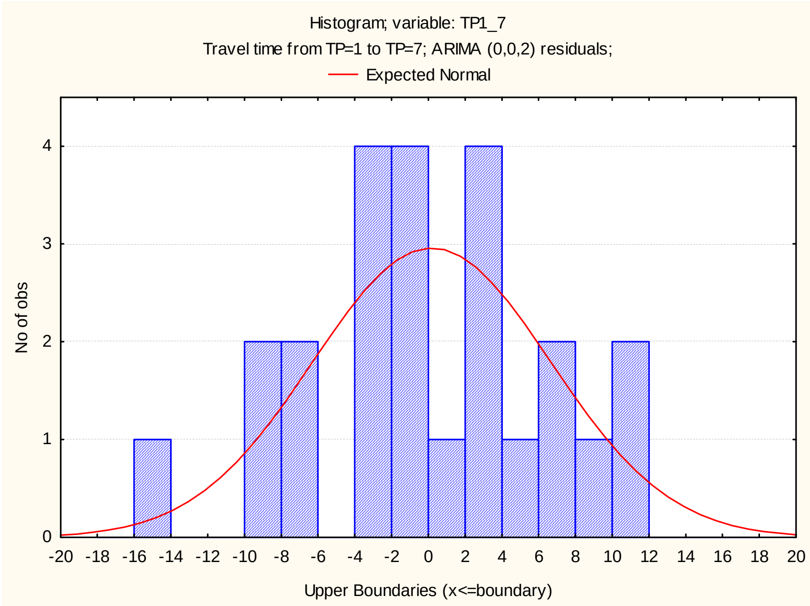


Figure 5.23 Histogram of the residuals of the bus travel time

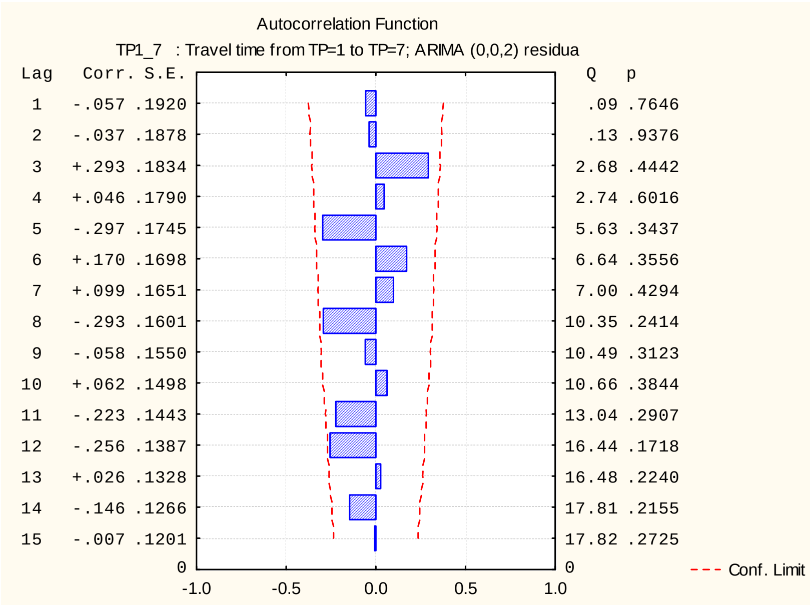


Figure 5.24 ACF of the residuals of the bus travel time

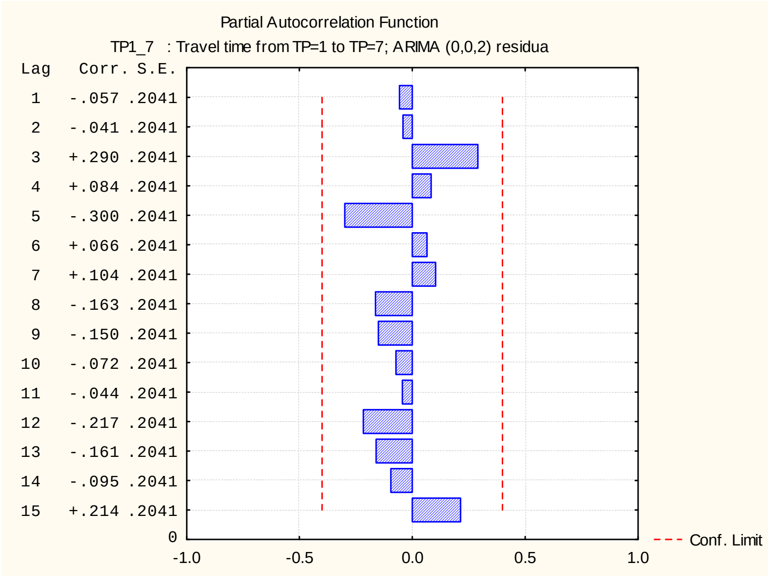


Figure 5.25 PACF of the residuals of the bus travel time

5.3.1.3 Application of bus travel time prediction

The performance of model is measured by degree of accuracy. Accuracy of the model is indicated by statistical closeness such as mean absolute relative error (MARE) and mean absolute percentage predicting error (MAPPE). Both are indicators of model performance based on residual of travel time. For instance, 10% was tolerable value for MAPPE although there is no specific requirement. The model which has minimum value of MARE and MAPPE is the accurate model (the best) among the several tentative models in predicting bus travel time. In other words, the minimum residual (error) indicate high accuracy model.

In application, the prediction of bus travel time with the model obtained is properly done by considering the value of MARE and MAPPE. Performance of models was measured by calculating MARE and MAPPE for each tentative model with formula:

$$MARE = \frac{1}{n}\sum_{i=1}^{n}\left|ActualValue - PredictedValue\right| \tag{5.4}$$

$$MAPPE = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{ActualValue - PredictedValue}{ActualValue}\times 100\right| \tag{5.5}$$

where, n : number of cases or data points

MARE in respective unit of minute

MAPPE is measured in %

The proper model is determined based on the MARE and MAPPE values among the tentative models as indicated by the minimum value of MARE and MAPPE. Table 5.22 shows MARE and MAPPE values. ARIMA(0,0,2) = MA(2) and ARIMA(0,0,1) = MA(1) are selected because of the smallest MARE and MAPPE values.

The MA(2) and MA(1) equation can be used to approximately generate the historical patterns of bus travel time in a time series and forecast the future value of the time series of bus travel time. For instance, the residual of travel time of 10% was tolerable, therefore, the route distance of 82.6 km which was traveled in a round trip within 240 minutes (4 hours), then the delay would likely being 24 minutes. The assumption of delay of 10% travel time seemed still reasonable for the regular stage bus which traditionally operated in mixed traffic. Meanwhile, for bus rapid transit (BRT) system generally concern with delay of 5 minutes which was tolerable.

In this case, both the model results could describe well the historical pattern of bus travel time with the minimum MAPPE values less than 10% (See Table 5.22). On the other hand, the delay as indicated by MARE values, both 4.44 and 6.77 minutes, were quite tolerable because those were not significant delay compared to the bus travel time of 117 and 123 minutes, respectively.

Table 5.22 Residual analysis and performance of models

Models	MARE (minute)	MAPPE (%)
Ipoh to Lumut Direction:		
a. ARIMA(0,0,1) = MA(1)	5.74	4.67
b. ARIMA(0,0,2) = MA(2)	4.44	3.88
c. ARIMA(1,0,0) = AR(1)	12.83	10.30
d. ARIMA(2,0,0) = AR(2)	74.34	64.24
Lumut to Ipoh Direction:		
a. ARIMA(0,0,1) = MA(1)	6.77	5.64
b. ARIMA(0,0,2) = MA(2)	7.86	6.42
c. ARIMA(1,0,0) = AR(1)	10.10	8.06
d. ARIMA(2,0,0) = AR(2)	30.56	24.66

Based on above explanation, the fit and suitable models of bus travel time prediction are:

a) Ipoh to Lumut:

$$Y_t = 116.1627 + 0.0447 * \varepsilon_{t-1} - 0.4289 * \varepsilon_{t-2} \tag{5.6}$$

b) Lumut to Ipoh:

$$Y_t = 122.2072 - 0.1218 * \varepsilon_{t-1} \tag{5.7}$$

Predicted and actual (observed) bus travel times were plotted with 95% confidence limit in Figure 5.26 and Figure 5.27. It was clearly shown that the bus travel time series vary stationary in mean value of 116.38 minutes for Ipoh to Lumut direction. Similarly, it varies in mean value of 122.25 minutes for Lumut to Ipoh direction. For both directions, there is no trend or linear relation between date and month of the year and bus travel time series. The most of data and predicted travel time for both Ipoh to Lumut and Lumut to Ipoh direction fell within 95% confidence limit, meaning that the models are reasonable and acceptable.

As shown in Figure 5.26 and Figure 5.27, also, the forecasting results indicated that there was no specific trend line showing the changes of bus travel time in the following period. In the following period, the average travel time for both directions would be 117 and 123 minutes, respectively.

The prediction was only based on the historical travel time data, other factors, like as road and traffic conditions were not considered. As well known, the upgrading of the existing highway to be divided 4-lane 2-way highway in this corridor was done from middle of 2006 and finished totally in September 2007. The traffic volume might change from time to time before and after upgrading work. Those factors were not accounted to this study as the upgrading of road was done per segment while data was collected by on board survey. In addition, the mixed-traffic condition would be varies per segment a long the corridor regarding the constructing work.

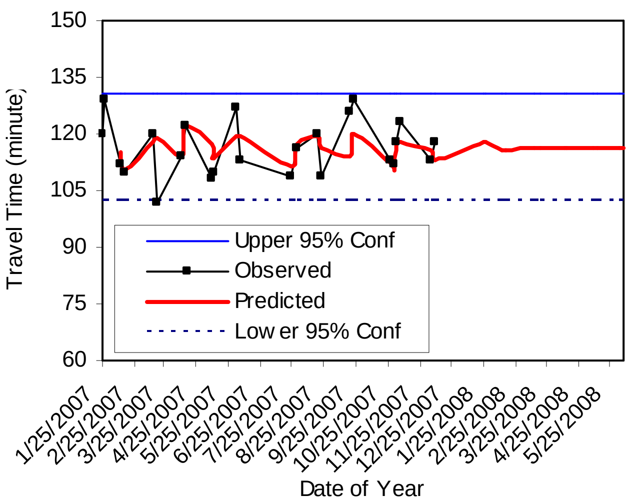


Figure 5.26 Travel time prediction (Ipoh to Lumut direction)

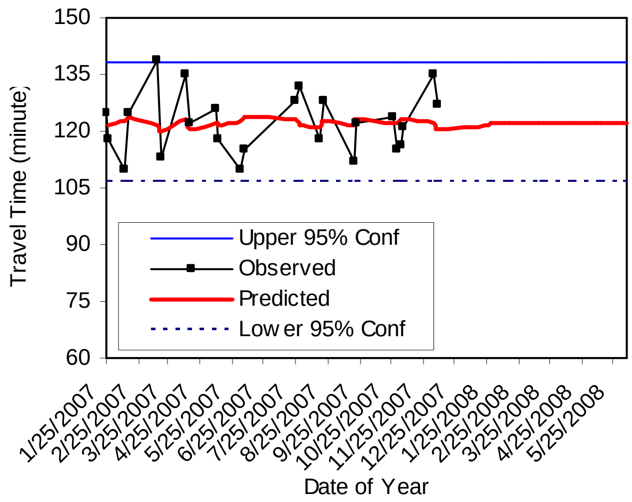


Figure 5.27 Travel time prediction (Lumut to Ipoh direction)

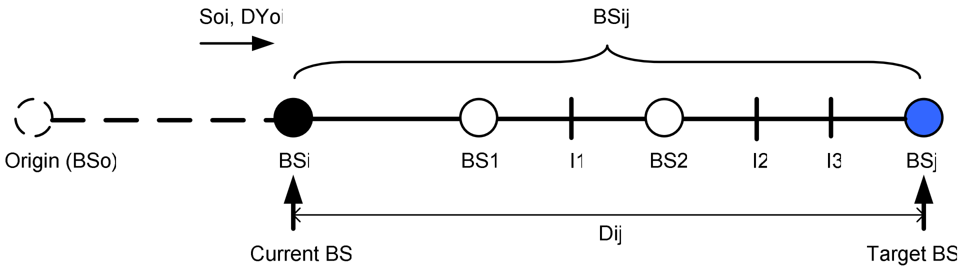
The predicted bus travel times by using the moving average model, MA(2) and MA(1) are close to the observed values as shown by the smallest values for both MARE and MAPPE. MA(2) and MA(1) models are appropriate to be applied for the bus travel time prediction for Ipoh to Lumut and Lumut to Ipoh directions, respectively. And both are statistical acceptable to be used in timetable design.

5.3.2 Multiple Linear Regressions

Multiple linear regressions is applied to identify selected determinant variables and to predict the travel time at certain stop point (bus stop) along the route. This section covers building models, multiple linear regression, testing of models and evaluation of models performance.

5.3.2.1 Building models

Statistical model was used to represent the change in bus travel time based on change in other variables identified. Historical data available included bus travel time, distance, speed, number of bus stop, delay from origin bus stop to current bus stop. Those primary data were collected during mid-day period of bus operation hours as well as recorded by GPS. Timetable or schedule of bus service operation was another important secondary data. From the both primary and secondary data then those are compiled in accordance to the list of selected variables. For instance, the variables used for building model of multiple regressions are described in Figure 5.28. The prediction model is applicable to bus travel time prediction during whole operation hours (7:00-21:00), as the data collected during the highest peak period, mid-day (11:00-15:00).



Note:

BS_o : bus stop at origin of trip
BS_i : current bus stop
BS_j : destination or target bus stop
BS_{ij} : number of bus stop from bus stop *i*-th to *j*-th
i,j : 1, 2, 3, etc.

I_{ij} : Number of intersection from current bus stop to target bus stop.
D_{ij} : distance from bus stop *i*-th to *j*-th in kilometer
S_{oi} : average speed from origin to current bus stop (bus stop *i*-th) in km/h
DY_{oi} : delay from origin bus stop to current bus stop in minute
TT_{ij} : travel time from current bus stop to target bus stop in minute

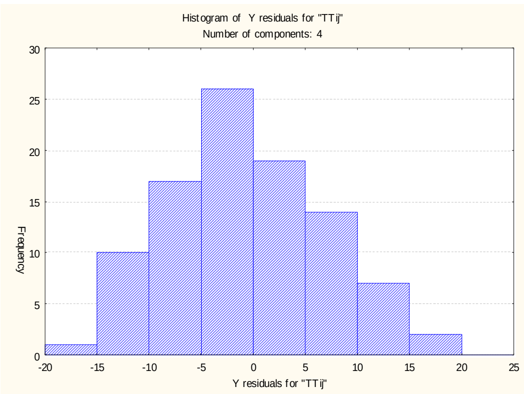
Figure 5.28 Modeling illustration

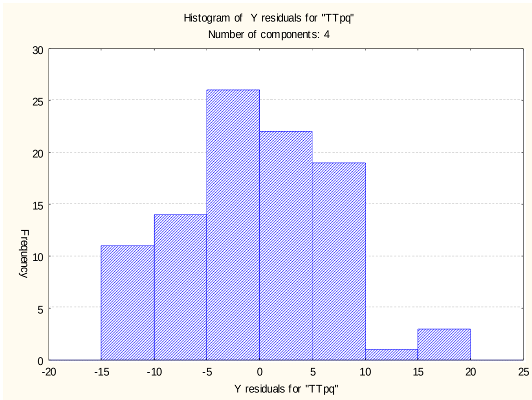
5.3.2.2 Multiple linear regressions

Table 5.23 Estimated parameters of the model shows the results of multiple linear regressions models by using STATISTICA software. Partial Least Squares module (PLS Multiple Regressions) is the method of analysis. The coefficients of regression obtained have the suitable sign which is rational common sense for the case. The sign are positive (+), negative (-) and positive (+) for the distance (D_{ij}, km), average speed (S_{oi}, km/h) and number of bus stop at a head (BS_{ij}), respectively. Both directions indicated the same reasonable coefficient sign, so that, the equation will be logical relation between travel time and three variables selected among the others. In other words, for Ipoh to Lumut direction (case 1), travel time (TT_{ij}) will increase with the increasing distance (D_{ij}) and number of bus stops (BS_{ij}). Meanwhile, travel time (TT_{ij}) will decrease if the average speed before current bus stop (S_{oi}) increases. With the same methods, for case 2 (Lumut to Ipoh direction), similar sign of coefficients are common sense. The residual of frequency of bus travel time were normally distributed as shown in Figure 5.29 and Figure 5.30. The model was developed separately into two cases due to the corridor of divided multiple-lane highway at which study done. The test on the coefficients of independent variable is explained later.

Table 5.23 Estimated parameters of the model

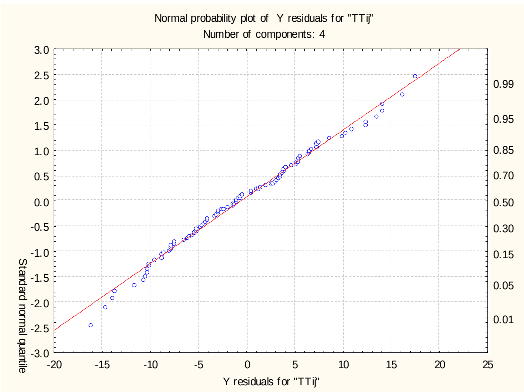
Case 1: Ipoh to Lumut direction PLS regression coefficients (MLR_TravelTime) Responses: TT_{ij} Options: INTERCEPT NOAUTOSCALE					Case 2: Lumut to Ipoh direction PLS regression coefficients (MLR_TravelTime) Responses: TT_{pq} Options: INTERCEPT NOAUTOSCALE				
	Interc.	D_{ij}	S_{oi}	BS_{ij}		Interc.	D_{pq}	S_{op}	BS_{pq}
TT_{ij}	62.16286	0.775679	-1.32787	1.531704	TT_{pq}	17.37501	1.086148	-0.361310	0.914559

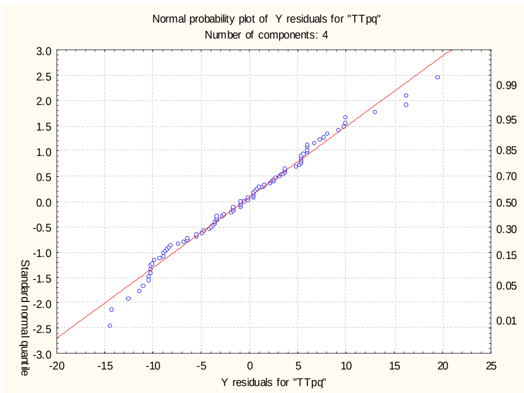




(a) Case 1: Ipoh to Lumut direction (b) Case 2: Lumut to Ipoh direction

Figure 5.29 Histogram of residual frequencies for bus travel time





(a) Case 1: Ipoh to Lumut direction (b) Case 2: Lumut to Ipoh direction

Figure 5.30 Normal probability plots of residual frequencies for bus travel time

Two variables such as number of intersection between current bus stop and target bus stop (I_{ij}) and delay from origin bus stop to current bus stop in minute (DY_{oi}) were dropped out from the analysis. Also, it was noted that Ipq and DY_{op} were dropped. For this case, after a trial statistical testing, both independent variables can not explain appropriately the variability of bus travel time. It was difficult to asses whether those independent variables giving positive or negative effect to dependent variable. This might be caused by the uncertainty of bus stopping at signalized or non-signalized intersection a long the respective segment in this mixed traffic. In other words, the more number of intersections may not cause increasing bus travel time due to no bus stopping for passengers. Other facts, in the mixed traffic there were delay propagation that is complex to model. Also, the state of delay at previous intersection will affect the effort of bus driver to maintain headway adherence onward of bus travel. Based on the aspects mentioned above, the I_{ij} and DY_{oi} (or I_{pq} and DY_{op}) are dropped for the limitation of study.

For explanation, below is the example of calculation from the case study on the Ipoh-Lumut corridor bus service. Data analysis given,

Origin bus stop (bus station) is Ipoh (BS_o)
Current bus stop is Bota Kanan (BS_i)
Target bus stop is Sitiawan (BS_j)
Distance from Bota Kanan to Sitiawan is 29.5 km (D_{ij})
Number of bus stops between Bota Kanan and Sitiawan are 13 (BS_{ij})
Average speed from origin to current bus stop is 47.9 km/h (S_{oi})
Number of intersection between current bus stop and target bus stop (I_{ij}) is 15
Delay from origin bus stop to current bus stop in minute (DY_{oi}) is 9 minutes
Travel time from current to target bus stop (TT_{ij}) in minute

a) <u>Ipoh to Lumut direction:</u>

For the Ipoh to Lumut direction, the result of multiple linear regression analysis was performed below (See Equation 5.8).

$$TT_{ij} = 62.16286 + 0.775679 D_{ij} - 1.332787 S_{oi} + 1.531704 BS_{ij} \qquad (5.8)$$

TT_{35} is travel time from time point or bus stop 3 to bus stop 5. In this case, bus stop 3 is Bota Kanan and bus stop 5 is Sitiawan. Actual TT_{ij} from bus stop 3 to bus stop 5 is

45 minutes, while the predicted TT_{ij} ($TT_{ij}PRE$) is 41.4 minutes. The calculation is presented in Table 5.24.

Table 5.24 Brief calculation for Ipoh to Lumut direction

TT_{ij}	D_{ij}	S_{oi}	BS_{ij}	I_{ij}	DY_oi	$TT_{ij}PRE$	Note
45	29.5	47.9	13	15	9		Data
45	29.5	47.9	13	-	-	41.4	STATISTICA software
45	29.5	47.9	13	-	-	41.4	MS Excel

b) Lumut to Ipoh direction:

Similarly, for the Lumut to Ipoh direction, multiple linear regressions model obtained is shown in Equation 5.9. The indices for the opposite direction, from Lumut to Ipoh were replaced with *p* and *q*. In this case, *p* = bus stop 5 and *q* = bus stop 3. TT_{53} is travel time between bus stop 5 (Sitiawan) and bus stop 3 (Bota Kanan). Calculation of travel time was presented in Table 5.25.

$$TT_{pq} = 17.37501 + 1.086148 D_{pq} - 0.36131 S_{op} + 0.914559 BS_{pq} \qquad (5.9)$$

Table 5.25 Brief calculation for Lumut to Ipoh direction

TT_{pq}	D_{pq}	S_{op}	BS_{pq}	I_{pq}	DY_{op}	$TT_{pq}PRE$	Note
44	29.5	33.1	13	15	11		Data
44	29.5	33.1	13	-	-	49.4	STATISTICA software
44	29.5	33.1	13	-	-	49.4	MS Excel

5.3.2.3 Testing of models validity (significance)

For this case, analysis of variance (ANOVA) test is used to test whether the regression explained by the model obtained is significant or not at the 0.05 level of significance. Significance of models was explained as below. For both two directions, the multiple linear regressions are significantly fitted to the observed or actual data as shown by the *F*–Statistic values. It means that the equation obtained can be used to predict or estimate travel time based on the change in explanatory variables, in this case distance, speed and number of bus stop.

Case 1: Ipoh to Lumut direction:

From the analysis of variance, the results showed the values of *R*-square = 0.959731; Adjusted *R*-square = 0.9574; Standard Error = 2.5609; and *F*–Statistic = 666.8351. The squared multiple correlation coefficient (R^2 = 0.9597) indicate that 95.97% of the variability in the "travel time" variable is explained by the 3 independent variables.

For instance, the 95.97% of the change in travel time can be explained by change in the 3 independent variables such as distance, average speed before current bus stop and number of bus stop. The analysis of variance (*F*-Statistic) indicated that the model was statistically significant, due to the *F*-Statistic = 666.8351 is higher than the value of Critical *F*-Statistic at 95% confidence limit which is 2.704. For the α = 5%, k = 3 and n-k-1 = 92, the value of Critical *F*-Statistic (Fα, k, n-k-1) = 2.704. The *p*-value of *F*-probability distribution with α=5%, df1=3 and df2=92 is 0.002946.

Case 2: Lumut to Ipoh direction:

From the analysis of variance, the results showed the values of *R*-square = 0.925209; Adjusted *R*-square = 0.9284; Standard Error = 2.1642; and *F*–Statistic = 810.3587. The squared multiple correlation coefficient (R^2 = 0.9252) indicate that 92.52% of the variability in the "travel time" variable is explained by the 3 independent variables. For instance, the 92.52% of the change in travel time can be explained by change in the 3 independent variables such as distance, average speed before current bus stop and number of bus stop. The analysis of variance (*F*-Statistic) indicated that the model was statistically significant, due to the *F*-Statistic = 810.3587 is higher than the value of Critical *F*-Statistic at 95% confidence limit which is 2.704. For the α = 5%, k = 3 and n-k-1 = 92, the value of Critical *F*-Statistic (Fα, k, n-k-1) = 2.704. The *p*-value of F-probability distribution with α=5%, df1=3 and df2=92 is 0.002946.

The significance of regression coefficient is evaluated by using the t-test. The regression coefficients are obtained as follows:

For Ipoh to Lumut direction: β_1 = 0.775679; β_2 = -1.332787; β_3 = 1.531704

For Lumut to Ipoh direction: β_1 = 1.086148; β_2 = -0.36131; β_3 = 0.914559

If the degree of significance is determined about 5% and the degree of freedom = 96-3 = 93, then we can see the value of *t*-Critical is 1.986. The values of *t*-Statistic for each variable are shown in Table 5.26.

Table 5.26 Value of t-Statistic

For Ipoh to Lumut direction:

	Coefficients	Standard error	t Stat	*p*-value
Intercept	62.16286	4.650761	1.837741	0.069328
D_{ij}	0.775679	0.041842	22.69986	1.79E-39
S_{oi}	-1.332787	0.102167	2.71863	0.089045
BS_{ij}	1.531704	0.12193	10.27357	6.09E-17

For Lumut to Ipoh direction:

	Coefficients	Standard error	t Stat	*p*-value
Intercept	17.37501	3.894208	-3.0212	0.00326
D_{pq}	1.086148	0.084156	10.36157	3.98E-17
S_{op}	-0.36131	0.098981	3.522722	0.000667
BS_{pq}	0.914559	0.238067	6.534763	3.48E-09

From Table 5.26, since the value of *t*-Statistic (calculated) of all independent variables (*D*, *S*, *BS*) exceed from value of *t*-Critical, this indicates that all independent variables (*D*, *S*, *BS*) could explain significantly the variability of dependent variable (*TT*, travel time). Otherwise, if value of *t*-Statistic ≤ *t*-Critical (table), it means that independent variables do not explain the variability of dependent variable *TT*. Hence, for both directions, it is clear that independent variables (*D*, *S*, *BS*) can significantly explain the variability of dependent variable (*TT*).

5.3.2.4 *Evaluation of models performance*

As mentioned in section 5.3.1, indicators of models performance were measured by using the similarity or statistical closeness between predicted and actual values. MARE stands for mean absolute relative error and MAPPE is abbreviation of mean absolute percentage error. MARE and MAPPE were calculated by using the Equation 5.10 and Equation 5.11.

$$MARE = \frac{1}{n}\sum_{i=1}^{n}\left|ActualValue - PredictedValue\right| \tag{5.10}$$

$$MAPPE = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{ActualValue - PredictedValue}{ActualValue}\times 100\right| \tag{5.11}$$

Where, n : number of cases or data points

MARE in respective unit of minute

MAPPE is measured in %

MARE and MAPPE represent average difference and percentage difference between the actual or observed travel time from current bus stop to target bus stop and predicted travel time. The MARE and MAPPE value for the models are shown in Table 5.27. At case 1, MLR model for Ipoh to Lumut direction had MARE of 6.1 minutes and MAPPE of 14.8%. Meanwhile, at case 2, MLR model for Lumut to Ipoh direction had MARE of 5.6 minutes and MAPPE of 12.1%. The MARE and MAPPE of both models are small and reasonable.

Table 5.27 MARE and MAPPE values of models for both directions

Case (direction)	MARE (minute)	MAPPE (%)
From Ipoh to Lumut	6.1	14.8
From Lumut to Ipoh	5.6	12.1

5.3.3 Statistica Neural Network (SNN) Model

The prediction of bus travel time from the current bus stop to the target bus stop was also well obtained by using Statistica Neural Network (SNN) (See Table 5.28 and Figure 5.33). RBF 3:3-4-1:1 model profile was adequate to model bus travel time prediction for both directions in the divided multiple lanes highway. These results have the same common sense with multiple linear regressions above (See section 5.3.1). The model performance was evaluated by using MARE and MAPPE formula given,

$$MARE = \frac{1}{n}\sum_{i=1}^{n}\left|ActualValue - PredictedValue\right| \tag{5.12}$$

$$MAPPE = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{ActualValue - PredictedValue}{ActualValue} \times 100\right| \tag{5.13}$$

Where, n : number of cases or data points

MARE in respective unit of minute

MAPPE is measured in %

5.3.3.1 Summary of models

After model specification done in the early step by using SNN tool and by following the process required than the results are presented. Table 5.28 showed the model summary reports for both Ipoh to Lumut and Lumut to Ipoh directions. Clearly, it was shown the list of model profile which was trained and selected by using the STATISTICA neural network tool. Five model profiles were resulted successfully reflecting the network set. Again, as the network's performance improves, the ratio becomes closer to zero.

In the model summary report, for both Ipoh to Lumut and Lumut to Ipoh directions, two model profiles obtained are the same. It was clearly revealed that model profile RBF 3:3-4-1:1 was the best model due to the lowest ratio of training error, selection error and test error. This value is ratio between the standard deviations of the residual and the target data. The result show that the network is successfully to use the information in the input variables, as it is indicated that the ratio much smaller than 1.0. Meanwhile, a ratio of 1.0 implies that the network is doing no better than the most naive estimation available and consequently that there is no useful information in the input variables. Beside, the RBF 3:3-4-1:1 model profile has the lowest errors due to training, selection and test steps. The average error would be the standard deviation of the target variable.

By proceeding steps, there would be displayed information window (See Figure 5.31) and Results (Run Models) window (See Figure 5.32). The generated spreadsheet containing the summary details of the network was shown in Table 5.28. There were 5 model profile listed with their network details. Index 1 to 5 (index = epoch) indicate that there are 5 retained networks which is selected based on the criteria of balance error against diversity. In other words, the index indicated a unique identifier assigned when the network is created and preserved throughout its lifetime. The one among the 5 retained networks is the best network found having very good performance (regression ratio and error of network selection) as shown in Figure 5.31.

(a) Ipoh to Lumut direction

(b) Lumut to Ipoh direction

Figure 5.31 Information window of the best network found

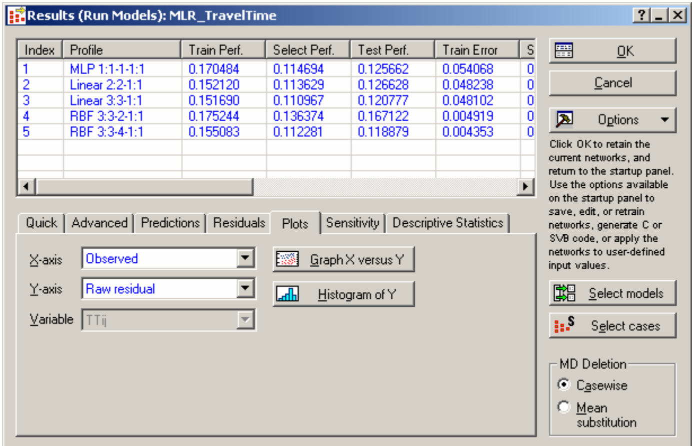


Figure 5.32 Results window for Ipoh to Lumut direction

The illustration of structure of selected network is shown in Figure 5.33. Type of model profile RBF 3:3-4-1:1 indicates a radial basis function network with 3 input variables, 1 output variable and three layers of neuron (3 input neurons, 4 hidden neurons and 1 output neuron). The symbols used in the illustration of a neural network are explained as the following. Unit activation levels by default are displayed in color as follows:

a. red color for positive activation levels, and
b. green color for negative activation levels.

Neurons are represented using one of several shapes:

a. Triangles. Triangles pointing to the right indicate input neurons. These neurons perform no processing and simply introduce the input values to the network.
b. Squares. Squares indicate Dot Product synaptic function units (e.g. as found in Multilayer Perceptrons).

c. Circles. Circles indicate Radial synaptic function units.

d. Small open circles. Input and output variables are illustrated using a small open circle joined to the corresponding input or output neuron. In some circumstances (nominal variables and time series inputs) a number of neurons are joined to a single input or output variable.

In both selected model profiles, the type of training algorithms used to optimize the neural network were KM, KN and PI. The code of KM stands for K-Means (center assignment). The code of KN stands for K-Nearest Neighbor (deviation assignment). The code of PI stands for Pseudo-Invert (linear least squares optimization).

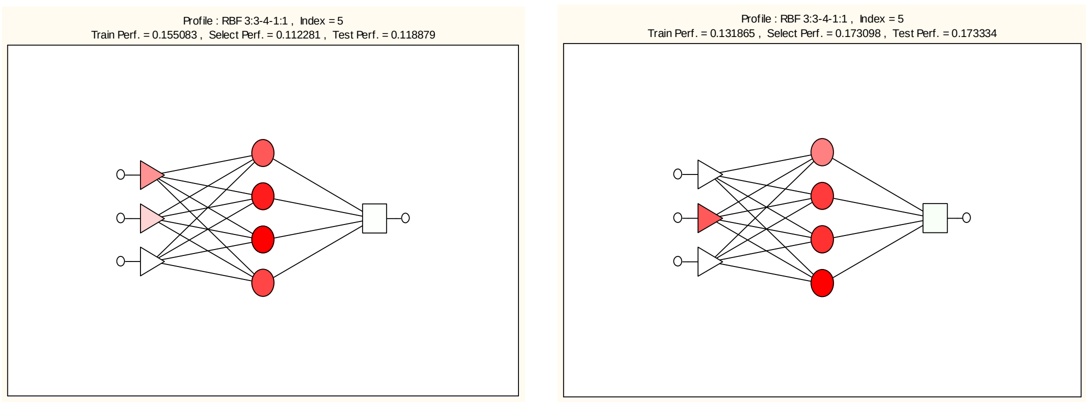
Table 5.28 Model summary report (SNN_TravelTime)

Model Summary Report (SNN_TravelTime) - Ipoh to Lumut direction:

Index	Profile	Train Perf.	Select Perf.	Test Perf.	Train Error	Select Error	Test Error	Training/ Members	Note	Inputs	Hidden (1)	Hidden (2)
1	MLP 1:1-1-1:1	0.170484	0.114694	0.125662	0.054068	0.041354	0.045469	BP100,CG20, CG26b		1	1	0
2	Linear 2:2-1:1	0.152120	0.113629	0.126628	0.048238	0.038459	0.045077	PI		2	0	0
3	Linear 3:3-1:1	0.151690	0.110967	0.120777	0.048102	0.038047	0.043956	PI		3	0	0
4	RBF 3:3-2-1:1	0.175244	0.136374	0.167122	0.004919	0.003976	0.005284	KM,KN,PI		3	2	0
5	RBF 3:3-4-1:1	0.155083	0.112281	0.118879	0.004353	0.003417	0.003929	KM,KN,PI		3	4	0

Model Summary Report (SNN_TravelTime) - Lumut to Ipoh direction:

Index	Profile	Train Perf.	Select Perf.	Test Perf.	Train Error	Select Error	Test Error	Training/ Members	Note	Inputs	Hidden (1)	Hidden (2)
1	Linear 1:1-1:1	0.156966	0.199393	0.221850	0.048831	0.069657	0.056863	PI		1	0	0
2	MLP 1:1-4-1:1	0.130859	0.170334	0.162832	0.040710	0.059517	0.041869	BP100,CG20, CG8b		1	4	0
3	MLP 1:1-3-1:1	0.130579	0.170163	0.160940	0.040626	0.059432	0.041422	BP100,CG20, CG7b		1	3	0
4	RBF 3:3-2-1:1	0.135515	0.174622	0.180990	0.003584	0.005231	0.004051	KM,KN,PI		3	2	0
5	RBF 3:3-4-1:1	0.131865	0.173098	0.173334	0.003488	0.005153	0.003889	KM,KN,PI		3	4	0



(a) Ipoh to Lumut direction (b) Lumut to Ipoh direction

Figure 5.33 Structure of selected network

5.3.3.2 Sensitivity analysis

Sensitivity analysis was conducted on each model and the best result was displayed in a spreadsheet (See Table 5.29). Sensitivity analysis was a technique to rates the importance of the models' input variables. The ratio is the basic measure of sensitivity (ratios of 1.0 or lower indicate an irrelevant or even damaging input variables, progressively higher values indicate more important variables). The ranking simply indicates the ordering of the ratios.

After sensitivities have been calculated for all variables, they may be ranked in order. These rankings make the interpreting of the sensitivities more convenience. A sensitivity of 1.0 means that input variable makes no contribution to the network's decision and can be pruned without any damage. In other words, the input variable has no effect on the performance of the network. Inputs with sensitivity below 1.0 actually damages network performance and should definitely be pruned. The sensitivity above 1.0, then there is some deterioration in performance, but this can be acceptable in order to reduce the network size.

In Ipoh to Lumut direction, the importance (ranking) of the variable sequentially are distance (D_{ij}), number of bus stop (BS_{ij}) and average speed before current bus stop (S_{oi}). Those were the same for the opposite direction, from Lumut to Ipoh direction, where distance is the most important variable followed by number of bus stop and average speed before current bus stop.

Table 5.29 Sensitivity analysis of the best model profile

Sensitivity Analysis - 5 (SNN_TravelTime) Ipoh to Lumut direction			
	D_{ij}	S_{oi}	BS_{ij}
Ratio.5	3.996254	1.125538	2.946107
Rank.5	1.000000	3.000000	2.000000

Sensitivity Analysis - 5 (SNN_TravelTime) Lumut to Ipoh direction			
	D_{pq}	S_{op}	BS_{pq}
Ratio.5	3.319056	1.127048	3.197389
Rank.5	1.000000	3.000000	2.000000

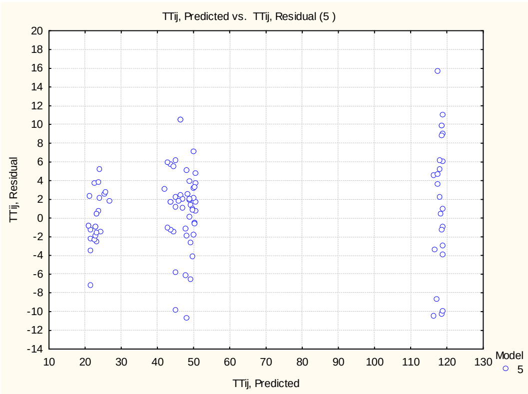
5.3.3.3 Descriptive statistics and residual analysis

Five regression model profiles were generated successfully from the three network types tested (linear, radial basis function (RBF), three layer perceptron (MLP)). Those five regression model profiles were shown in index 1 to 5 such as MLP 1:1-1-1:1, Linear 2:2-1:1, Linear 3:3-1:1, RBF 3:3-2-1:1 and RBF 3:3-4-1:1. Table 5.30 provided descriptive statistic and residual of five model profiles such as data mean, data standard deviation, error mean, error standard deviation, absolute error mean, standard deviation ratio and correlation. Column $TT_{ij}.5$ and $TT_{pq}.5$ were about descriptive statistic of the selected model profiles for Ipoh to Lumut and Lumut to Ipoh directions, respectively. In addition, from Figure 5.34, it could be shown the scatter plot of residual against predicted values of bus travel time.

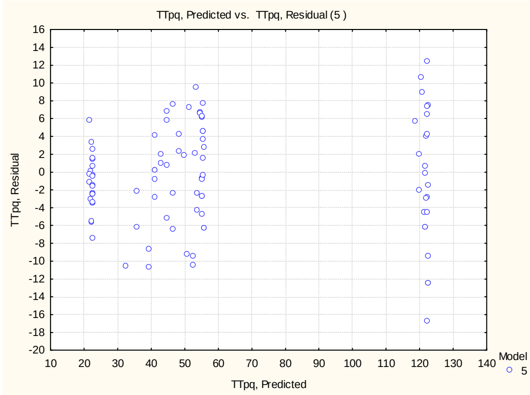
The characteristics of normal distribution for observed, predicted and residual values of bus travel time were described in Figure 5.35 and Figure 5.36. Figure 5.35 (a) and Figure 5.36 (a) showed the histogram frequency of observed and predicted bus travel time in which curve line explaining their normal distribution. From the residual analysis (See Figure 5.35 (b) and Figure 5.36 (b)), it was clearly shown that residual values for both direction look well normally distributed, so that the selected model profiles appropriately depicted the best regression model.

Table 5.30 Descriptive statistics of the five model profiles

Description	Regression (1-5) (SNN_TravelTime) Ipoh to Lumut direction					Regression (1-5) (SNN_TravelTime) Lumut to Ipoh direction				
	TTij.1	*TTij*.2	*TTij*.3	*TTij*.4	*TTij*.5	*TTpq*.1	*TTpq*.2	*TTpq*.3	*TTpq*.4	*TTpq*.5
Data Mean	58.18750	58.18750	58.18750	58.18750	58.18750	61.12500	61.12500	61.12500	61.12500	61.12500
Data S.D.	35.29852	35.29852	35.29852	35.29852	35.29852	37.42444	37.42444	37.42444	37.42444	37.42444
Error Mean	1.02454	0.83131	0.90335	0.90939	0.96912	-0.10082	-0.08933	-0.12840	-0.64011	-0.53987
Error S.D.	5.29755	4.89973	4.83794	5.89379	4.91523	6.74521	5.52025	5.49987	5.79749	5.66007
Abs E. Mean	4.34010	3.80911	3.69528	4.67228	3.80877	5.42377	4.23941	4.22724	4.55913	4.51966
S.D. Ratio	0.15008	0.13881	0.13706	0.16697	0.13925	0.18024	0.14750	0.14696	0.15491	0.15124
Correlation	0.98879	0.99062	0.99083	0.98616	0.99043	0.98363	0.98907	0.98916	0.98795	0.98852

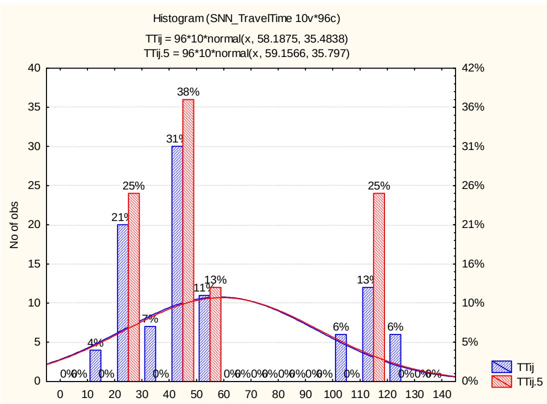


(a) Ipoh to Lumut direction

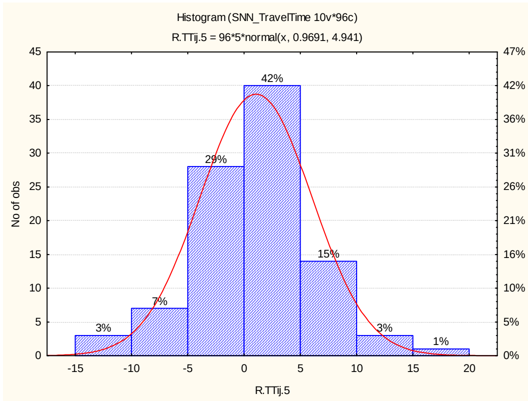


(b) Lumut to Ipoh direction

Figure 5.34 Plot of residual against predicted bus travel time

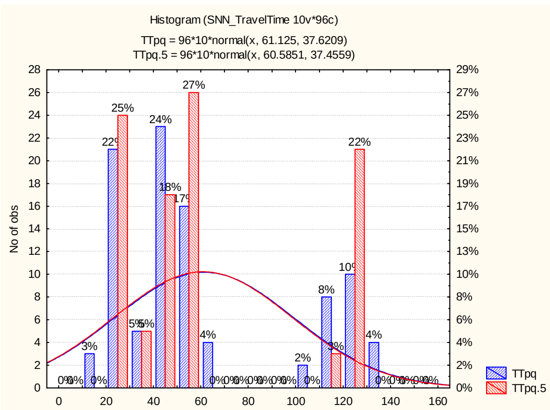


(a) Observed and predicted values

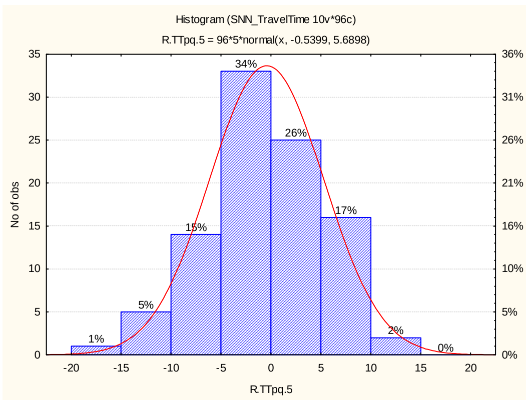


(b) Residual values

Figure 5.35 Observed, predicted and residual of bus travel time (Ipoh to Lumut)



(a) Observed and predicted values

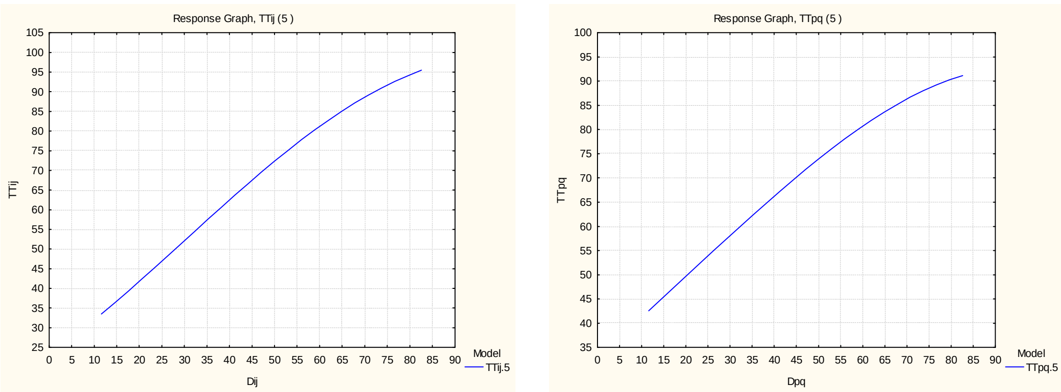


(b) Residual values

Figure 5.36 Observed, predicted and residual of bus travel time (Lumut to Ipoh)

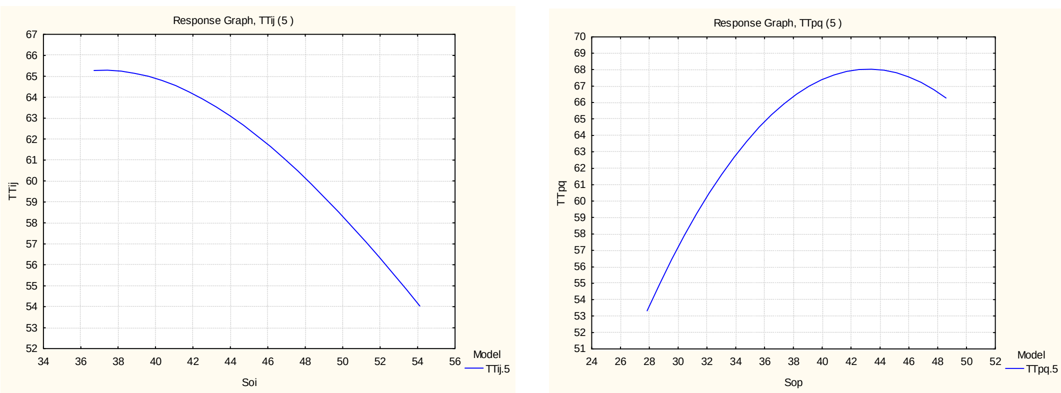
5.3.3.4 Response bus travel time against variables

According to selected model, the increase of distance from current bus stop to target bus stop would influence the increase of bus travel time. Both Ipoh to Lumut and Lumut to Ipoh direction had the same effect on the increasing of bus travel time (See Figure 5.37). Figure 5.38 (a) showed that bus travel time would increase if the average speed before current bus stop would decrease. Meanwhile, the bus travel time would increase if the average speed before current bus stop (*S*) would increase over low speed period or if the average speed before current bus stop (*S*) would decrease over high speed period (See Figure 5.38 (b)). The number of bus stops from the current bus stop to target bus stop also significantly affected the change of bus travel time. The more number of bus stops, the more the bus travel time would be (See Figure 5.39).



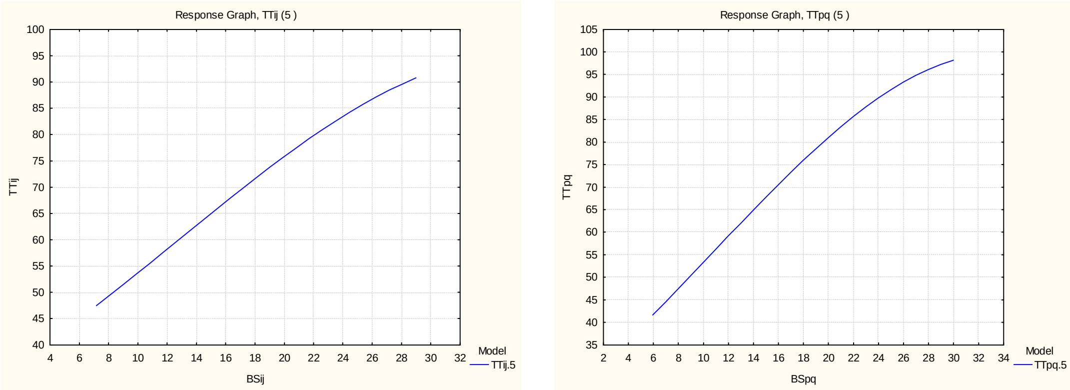
(a) Ipoh to Lumut direction (b) Lumut to Ipoh direction

Figure 5.37 Travel time response against distance between two bus stops



(a) Ipoh to Lumut direction (b) Lumut to Ipoh direction

Figure 5.38 Travel time response against average speed



(a) Ipoh to Lumut direction (b) Lumut to Ipoh direction

Figure 5.39 Travel time response against bus stops number

5.3.3.5 Evaluation of models and user defined cases prediction

Evaluation of model performance separately was carried out by calculating the MARE and MAPPE values. MARE and MAPPE value of the same model profile (RBF 3:3-4-1:1) for both directions were shown Table 5.31. For the selected model profile (RBF 3:3-4-1:1) at Ipoh to Lumut direction, the MARE value is 3.81 minutes and the MAPPE value is 7.56%. Meanwhile, at Lumut to Ipoh direction both MARE and MAPPE values are 4.52 minutes and 8.66%, respectively. The MARE and MAPPE of both models are small and reasonable. In other words, MARE values was assumed as delay or error, thus the error or delay of 3.81 and 4.52 minuets were not significant compared to average bus travel time of 117 and 123 minutes, respectively. Figure 5.40 showed the spatial behavior of the prediction error for the selected model (index 5) for both Ipoh to Lumut and Lumut to Ipoh directions. It is clear fact that the error (MAPPE value) increase from Ipoh (start terminal) to Lumut (end terminal) direction, as shown by the MAPPE *TTij*.5 line. Again, the same fact occurs for the direction from Lumut (start terminal) to Ipoh (end terminal). This shows the cumulative error along the travel.

Table 5.31 Performance values of the model profiles

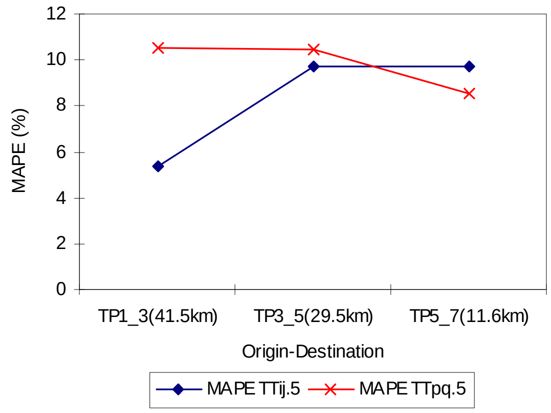
Ipoh to Lumut direction

	TTij.1	*TTij*.2	*TTij*.3	*TTij*.4	*TTij*.5 *)
MARE (minute)	4.34	3.81	3.70	4.67	3.81
MAPPE (%)	8.78	7.53	7.11	10.12	7.56

Lumut to Ipoh direction

	TTpq.1	*TTpq*.2	*TTpq*.3	*TTpq*.4	*TTpq*.5 *)
MARE (minute)	5.42	4.24	4.23	4.56	4.52
MAPPE (%)	11.27	7.99	7.97	8.59	8.66

Note: *) selected model



Note: TT_{ij} = from Ipoh to Lumut direction and

TT_{pq} = from Lumut to Ipoh direction

Figure 5.40 Spatial behavior of prediction error (MAPPE value)

By using Run Existing Model dialog the prediction based on the user defined cases could be performed. In this dialog it can be explore the results in quick tab, advanced tab and prediction tab. In this case, the user defined cases prediction can be performed for both Ipoh to Lumut direction and Lumut to Ipoh direction. Table 5.32 shows the results of user defined cases prediction for the best model RBF 3:3-4-1:1 (index 5).

Table 5.32 User defined cases prediction using selected model RBF 3:3-4-1:1

	Ipoh to Lumut direction					*Lumut to Ipoh direction*			
	User defined case prediction, (5) (SNN_TravelTime)					User defined case prediction, (5) (SNN_TravelTime)			
	D_{ij}	S_{oi}	BS_{ij}	*TTij*.5		D_{pq}	S_{op}	BS_{pq}	*TTpq*.5
1	41.5	43.1	7	48.4	1	11.6	45.1	6	25.1
2	41.5	40.0	7	49.8	2	11.6	39.0	6	22.5
3	41.5	40.6	7	49.5	3	11.6	43.9	6	24.5
4	41.5	44.3	7	47.9	4	11.6	45.5	6	25.3
5	41.5	38.7	7	50.4	5	11.6	42.7	6	24.0
6	41.5	42.0	7	48.9	6	11.6	41.3	6	23.4
7	41.5	37.5	7	50.8	7	11.6	45.5	6	25.3
8	41.5	38.7	7	50.4	8	11.6	39.3	6	22.6
9	41.5	43.1	7	48.4	9	11.6	38.4	6	22.3
10	41.5	45.1	7	47.5	10	11.6	43.9	6	24.5
11	41.5	42.0	7	48.9	11	11.6	44.3	6	24.7
12	41.5	39.3	7	50.1	12	11.6	42.0	6	23.7
13	41.5	40.6	7	49.5	13	11.6	40.3	6	23.0
14	41.5	36.7	7	51.1	14	11.6	43.9	6	24.5
15	41.5	43.9	7	48.1	15	11.6	42.0	6	23.7
16	41.5	35.7	7	51.5	16	29.5	33.1	13	45.7
17	41.5	39.6	7	50.0	17	29.5	30.3	13	44.2
18	41.5	45.1	7	47.5	18	29.5	30.3	13	44.2
19	41.5	42.0	7	48.9	19	29.5	24.9	13	41.9
20	41.5	39.6	7	50.0	20	29.5	24.9	13	41.9
21	41.5	39.6	7	50.0	21	29.5	29.0	13	43.6
22	41.5	39.6	7	50.0	22	29.5	27.8	13	43.1
23	41.5	39.6	7	50.0	23	29.5	27.8	13	43.1
24	41.5	39.6	7	50.0	24	29.5	27.8	13	43.1
25	41.5	39.6	7	50.0	25	29.5	26.8	13	42.6
26	41.5	39.6	7	50.0	26	29.5	29.0	13	43.6
27	29.5	48.8	13	46.3	27	29.5	27.8	13	43.1
28	29.5	42.2	13	49.0	28	29.5	31.6	13	44.9
29	29.5	50.8	13	45.7	29	29.5	31.6	13	44.9
30	29.5	51.9	13	45.4	30	29.5	34.8	13	46.6
31	29.5	53.0	13	45.1	31	29.5	33.1	13	45.7
32	29.5	50.8	13	45.7	32	29.5	30.3	13	44.2
33	29.5	50.8	13	45.7	33	29.5	36.6	13	47.6
34	29.5	54.1	13	44.8	34	29.5	31.6	13	44.9
35	29.5	48.8	13	46.3	35	29.5	23.2	13	41.3
36	11.6	39.3	8	23.2	36	41.5	40.2	11	54.1
37	11.6	37.7	8	24.3	37	41.5	40.2	11	54.1
38	11.6	45.4	8	20.7	38	41.5	46.6	11	57.1
39	11.6	46.6	8	20.5	39	41.5	40.2	11	54.1
40	11.6	40.2	8	22.7	40	41.5	35.4	11	51.3
41	11.6	47.8	8	20.4	41	40.0	40.0	10	51.2
42	11.6	42.1	8	21.7	42	40.0	35.0	10	48.4
43	11.6	41.2	8	22.2	43	80.0	40.0	30	118.0
44	11.6	42.1	8	21.7	44	80.0	35.0	30	113.7
45	11.6	45.4	8	20.7	45	80.0	45.0	30	119.8
46	11.6	35.4	8	26.0	46	80.0	50.0	30	118.9
47	12.0	35.0	8	26.2	47	80.0	40.0	25	111.8
48	80.0	42.0	29	116.4	48	80.0	45.0	30	119.8
49	80.0	45.0	30	115.3	49	80.0	50.0	30	118.9
50	30.0	48.0	13	47.0	50	80.0	45.0	35	122.6

5.4 Summary

The operational measurement of bus service characteristics have been identified such as vehicle and passenger characteristics, service frequency, load factor and lost time. A number of performance indicators of bus operation were analyzed extensively to evaluate the reliability of bus service such as on-time performance, service regularity, punctuality index and expected average waiting time.

The high headway reflected the low service frequency and caused long waiting time, thus makes the current bus system is unattractive to passengers. The bus availability of 100% is very satisfactory even the load factor is low. The number of passengers and load factor will increase if the headway is decreased. Shorter headway was designed to shorten waiting time, so the bus will be more attractive to passengers.

The on-time performance and service regularity of stage bus in mixed traffic can be derived by using the data collected from onboard survey. The results show clearly that stage bus operated in mixed traffic can be categorized as low on-time performance and low service regularity. These two approaches could measure the reliability of bus service. In other words, the reliability was low.

The bus operation characteristics and performance indicators are compared to the standard as a general guidance to judge the viability of bus operation. In this case, the bus service characteristics and performance indicators were not satisfactory compared to standard (World Bank) as a general guidance to judge the viability of city bus operation. Thus, the bus was more relevant to be categorized into intercity bus. In the local implementation of bus system standard, it is necessary to make adjustment upon the local resources, region potencies, assumptions and other limitations. Consecutively, the results will be useful for operator/investor, regulator and customers/users as consideration in enhancing quality, efficiency and effectiveness of bus service delivery and operations.

The predicted travel times by using the moving average model, MA(2) and MA(1) are close to the observed values. Those are indicated by the MARE and MAPPE values. The moving average models obtained had minimum MARE and MAPPE values compared to other tentative ARIMA models which being assessed. Those mean that MA(2) and MA(1) models are appropriate to be applied for the bus travel time prediction for Ipoh to Lumut and Lumut to Ipoh direction, respectively. And, those models can be used for bus travel time prediction in the case and they were statistically accepted to be used in timetable design.

Multiple linear regressions was applied to identify selected determinant variables and to predict the travel time at certain stop point (bus stop) along the route. From the data analysis, the results show that multiple linear regressions (MLR) were adequate to model the bus travel time prediction. The model was developed separately into two cases due to the corridor of divided multiple-lane highway in which study was carried out. The validity or significance of both models was tested by using ANOVA test. The models were significantly fitted based on ANOVA test at 95% confidence limit. Moreover, the model performance was evaluated by using the MARE and MAPPE values. At case 1, MLR model for Ipoh to Lumut direction had MARE of 6.1 minutes and MAPPE of 14.8%. Meanwhile, at case 2, MLR model for Lumut to Ipoh direction had MARE of 5.6 minutes and MAPPE of 12.1%. The MARE and MAPPE of both models are small and reasonable values, therefore, models were adequate for bus travel time prediction.

This study recommend to apply the empirical equation (multiple linear regressions, MLR) of bus travel time by considering some independent variables which closely related to the system as well tested such as distance, average speed and number of bus stop. This study contributes to the evaluation and redesigning of timetable of bus service operation, especially for long distance bus route operation in the mixed traffic. For advance, it is applicable for information development of bus travel time. The study is limited to discuss on three independent variables as mentioned above and therefore, future research are highly suggested for more independent variables.

In other way, the prediction of bus travel time from the current bus stop to the target bus stop was also well obtained by using Statistica Neural Network (SNN), thus RBF 3:3-4-1:1 model profile was adequately obtained. The result indicated that the prediction of bus travel time from the current bus stop to the target bus stop was performed well by using Statistica Neural Network (SNN). In this case, the radial basis function (RBF 3:3-4-1:1) is the best model profile for bus travel time prediction compared to linear and multilayer perceptrons (MLP) model profile regarding to smallest regression ratio and error of model selection. A number of related factors such as distance, average speed and number of bus stops are the quite significant factors influencing the change of bus travel time. Those input variables that intuitively selected are meaningful in predicting the bus travel time. The bus travel time increases as the distance and number of bus stops from current bus stop to target bus stop increases. Meanwhile, the higher the average speed approaching current bus stop, the bus travel time from current bus stop to target bus stop will be lower.

RBF 3:3-4-1:1 model profile was adequate to model the bus travel time prediction. The same model profile was obtained for both two directions due to the corridor of divided multiple lanes highway in which study was carried out. The model performance was evaluated by using the MARE and MAPPE values. At case 1, selected SNN model for Ipoh to Lumut direction had MARE of 3.81 minutes and MAPPE of 7.56%. Meanwhile, at case 2, selected SNN model for Lumut to Ipoh direction had MARE of 4.52 minutes and MAPPE of 8.66%. The MARE and MAPPE of both models are small and reasonable. This study also recommended the prediction of bus travel time by using neural network model could consider input variables such as distance, average speed and number of bus stop. The user defined cases prediction also could be performed by running the existing selected network.

CHAPTER 6
ANALYSIS OF BUS SERVICE IMPROVEMENT

6.0 Overview

This chapter is strongly focused on the effort on how to improve the current bus service. In addition, the analysis of bus service demand is introduced prior to exploring the strategic operational planning in association with bus service improvement. Qualitative and quantitative analysis are comprehensively performed to support in making decision of choosing a number of solutions for improvement. The content of this chapter includes sections and sub sections such as demand of bus service analysis, bus service improvement strategy, demand sensitivity, model of bus service demand, measurements and indicators of improvement and trip distribution analysis. At the end, whole idea and discussion are summarized in chapter summary.

6.1 Bus Service Demand Analysis

In this section, the analysis of demand for bus service aims at measuring and estimating the travel demand which utilizing existing bus service. To reach the same point of view regarding to travel demand for public transportation, a term of travel demand which using bus service as an existing public transportation mode in this corridor is further called bus service demand. Generally, the basic data for analysis bus service demand is collected by on-board survey. On-board survey aims at collecting data of bus service operation and counting the number and characteristic passengers use bus. From the data analysis, basic information on the number of passengers boarding and alighting along the bus route is obtained. As usual, it can be visualized into a graph named loading profile. Moreover, the measures of characteristics of demand can further be calculated, analyzed and assessed.

Schedule of data collection is divided into three categories for representing time-based people's mobility and activities (See Appendix A.1). The first on-board survey was conducted for whole day starting from 07:00 to 20:30. The full one day survey was done on typical workday. The result of analysis of passengers shows the number of passengers during morning peak, mid-day peak and afternoon peak. The highest is at mid-day (11:00 – 15:00), therefore, mid-day period was chosen in conducting the on-board survey for representing data over one week and one year period. One week and one year data were collected for both workday and weekend typical day.

In relation with spatial-based people's mobility and activity, from the on-board survey, the distribution of passengers according to stop location along the bus route can be determined. As being designed, on-board survey were done for two-way bus trip such as Ipoh to Lumut direction and Lumut to Ipoh direction, with total of distance 2 x 82.6 km. Bus usually run over the route for during 4 hours for two-way.

6.1.1 Boarding and Alighting Passengers and Zoning

Figure 6.1 shows the illustration of boarding and alighting passengers and zoning. The three zones according to district administrative which exist along the Ipoh-Lumut corridor are Kinta, Perak Tengah and Manjung. The existing bus route link Ipoh bus station (Medan Kidd bus station) and Lumut bus station. There are two bus stations or terminals within this route such as Seri Iskandar bus station and Manjung bus station.

There are three types of condition or activities at the stop location:

1. only boarding passengers (start from bus station)
2. only alighting passengers (one or more alighting passengers at any stop location)
3. both boarding and alighting passengers (one or more boarding and alighting passenger at the same time and stop location)

The stop location, noted with i, is arbitrary location where bus stopped for boarding and alighting passengers. Where, i = 1, 2, 3, 4,… n. The number of stop (n) can be the same or different between 1^{st} trip and 2^{nd} trip. And also, the location of stop can be the same or different between two directions. For the 1^{st} and 2^{nd} trip, at a stop location there will be only boarding passengers, only alighting passengers or both boarding and alighting passengers. It is depend on passenger needs of activities.

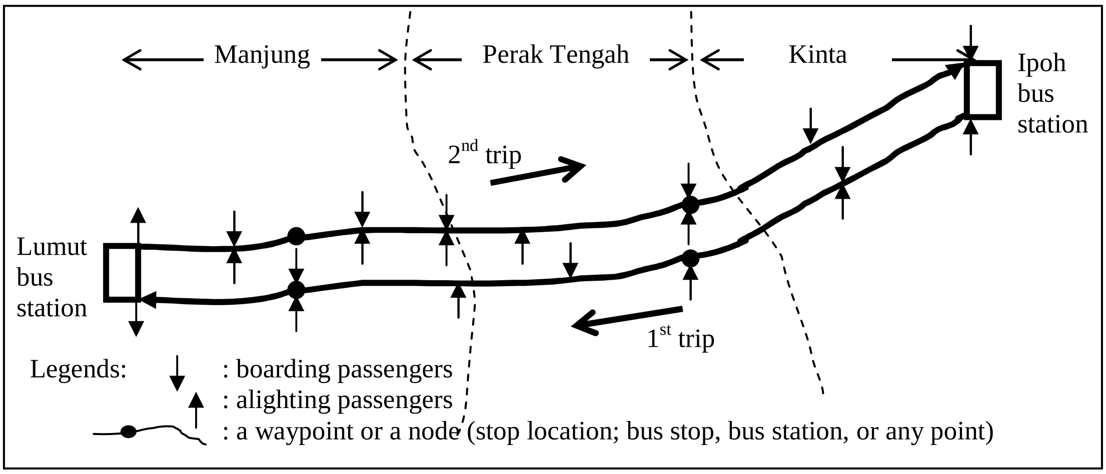


Figure 6.1 Illustration of boarding and alighting passengers and zoning

Zone definition is made based on the administrative district boundaries. Table 6.1 shows three district which laying along the Ipoh-Lumut corridor as three main zones. Detail about sub zone is shown in Table 6.2. The name of location and code of waypoint can be seen in Table 6.3.

Table 6.1 Definition of zone

Zone	Description		Length
	From	To	(km)
1. Kinta	Ipoh bus station Waypoint P1 Km 0.0	Taman Maju Waypoint 276 Km 30.2	30.2
2. Perak Tengah	Taman Maju Waypoint 276 Km 30.0	Kg. Ct Chermin Waypoint 367 Km 49.4	19.4
3. Manjung	Kp. Ct Chermin Waypoint 367 Km 49.4	Lumut bus station Waypoint 478 Km 82.6	33.2
	Total length of corridor		82.6

Table 6.2 Definition of sub zone

Zone	Description	Length (km)	Stationing
1. Kinta			
a. Ipoh	Medan Kids bus station	0.0	0.0
b. Menglembu/Lahat	Ipoh – Menglembu – Lahat Wpt P1 (km 0.0) to Wpt 188 (km 9.82)	9.82	9.82
c. Pusing/Seputeh/UTP	Papan/Pusing – Seputeh – Tronoh – UTP Wpt 188 (km 9.82) to Wpt 276 (km 30.2)	20.38	30.2
2. Perak Tengah			
a. Bandar Seri Iskandar	Taman Maju – Bus station - Pentadbiran Perak Tengah – Ct. Sodang/IKBN Wpt 276 (km 30.0) to Wpt 299 (km 34.9)	4.7	34.9
b. Bota Kanan	Ct. Sodang/IKBN – Pentadhbiran Perak Tengah – Bota Kanan Wpt 299 (km 34.9) to Wpt 339 (km 42.6)	7.7	42.6
c. Bota Kiri	Bota Kiri – Titi Gantong - Kg. Ct. Chermin Wpt 339 (km 42.6) to Wpt 367 (km 49.4)	6.8	49.4
3. Manjung			
a. Ayer Tawar	APL industry (Kg. Ayer Tawar) – Junction to Pt. Remis – Ayer Tawar – Junction to Sitiawan (Kg. Deralik) Wpt 367 (km 49.4) to Wpt 410 (km 66.5)	17.1	66.5
b. Sitiawan	Sitiawan (Kg. Deralik) – Sitiawan (Sp Empat) - Manjung Wpt 410 (km 66.5) to Wpt 435 (km 73.9)	7.4	73.9
c. Manjung	Manjung bus station - Kg. Batu Tiga – Kg. Pundut – Lumut bus station Wpt 433 (km 73.9) to Wpt 478 (82.6)	8.7	82.6
d. Lumut	Lumut bus station	0.0	82.6
	Total length of corridor	82.6	

Note: Wpt : code of waypoint from GPS data

Table 6.3 The name of location and code of waypoint

Zone	Waypoint	Kilometer
1. Kinta		
a. Ipoh bus station	P1	0.0
b. Menglembu	093	4.78
c. Lahat	183	8.37
d. Papan	203	11.9
e. Pusing	210	16.3
f. Seputeh	228	18.2
g. Tronoh	250	23.4
h. UTP	265	27.6
2. Perak Tengah		
a. Tn Maju/Hentian Bus Seri Iskandar	276	30.2
b. UiTM/Perak Tengah	291	32.9
c. Ct. Sodang	299	34.9
d. Bota Kanan	J0054	41.5
e. Bota Kiri	BS10	43.1
f. Titi Gantong	349	44.8
g. Kg. Ct. Chermin	367	49.4
3. Manjung		
a. APL industry/Kg. Ayer Tawar	380	53.0
b. Junction to Pt. Remis	390	54.6
c. Ayer Tawar	396	59.1
d. Kg. Baharu/Ayer Tawar	399	60.5
e. Junction to Sp Lima	023	63.9
f. Kg. S. Wangi	406	64.9
g. Junction to Sitiawan (Kg. Deralik)	410	66.5
h. Sitiawan, junction	426	71.0
i. Manjung bus station	135	75.3
j. Kg. Batu Tiga, junction	443	76.1
k. Kg. Pundut	454	78.7
l. Lumut bus station	478	82.6

6.1.2 Spatial-Based Demand of Bus Service

Demand analysis of bus service is categorized into spatial-based demand and time-based demand. Spatial-based demand is to describe the potential and distribution of passengers of bus service along the operational route. In this category, zoning is determined based on the distance between points a long the route starting from Ipoh bus station to Lumut bus station. And also, time-based demand is to identify potential demand regarding to period of service in order to optimize operational service frequency, operating hour and management.

Figure 6.2 and Figure 6.3 show scatter plot of passengers per bus per trip. The number of passengers gets on bus at Ipoh bus station (km 0) to Lumut bus station (km 82.6) is higher than those at bus stop along this route. This represents that Ipoh and

Lumut bus station are end-to-end terminal which being dominant origin or destination. Ipoh bus station is always crowded with higher number of passengers get on (See Figure 6.2) and passengers get off (See Figure 6.3) compared to Lumut bus station. From both figure, a number of bus stop locations along the route which have relatively high number of passengers are Taman Maju (km 30.2), Bota Kanan (km 41.5), Ayer Tawar (km 59.1), Sitiawan (km 71) and Manjung bus station (km 75.3). So that, those locations are assumed as the important point for analysis of bus service characteristics and demand of public transportation.

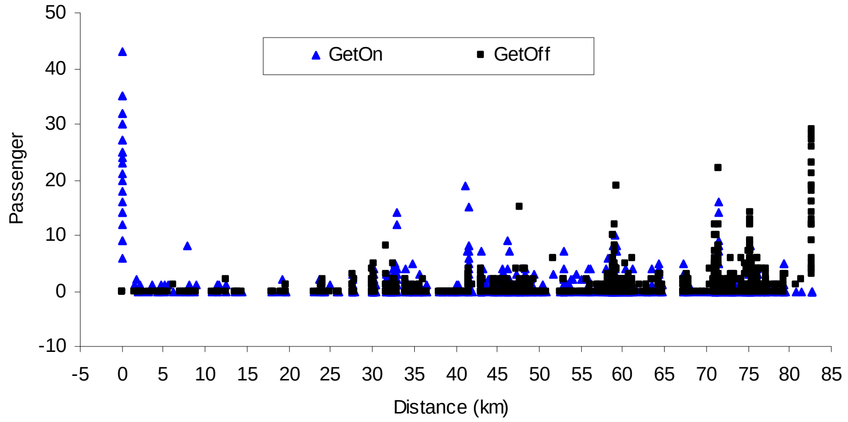


Figure 6.2 Scatter plot of passengers per bus per trip in Ipoh-Lumut direction

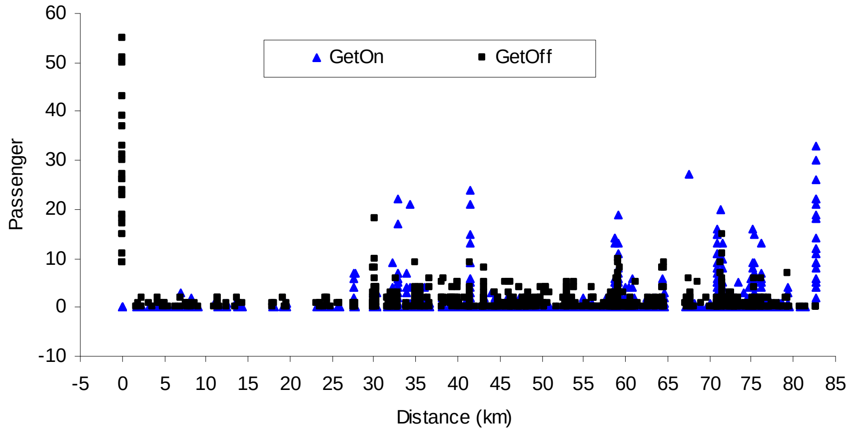


Figure 6.3 Scatter plot of passengers per bus per trip in Lumut-Ipoh direction

Table 6.4 show the average number of passengers per bus per day using bus service in Ipoh-Lumut highway. For two-way trip the productivity is 366 pass/bus/day. This number reflects trip productivity of bus service for both directions. In one trip from departure at bus station (Ipoh) to the end trip (Lumut) or vice versa, number of passengers getting on bus is ideally the same as number of passengers getting off bus. If we look detail, the trip productivity from Ipoh to Lumut direction (172 pass/bus/day) is less than that of Lumut to Ipoh direction (194 pass/bus/day). It may be possible because people use other transport mode for their commuting instead of using bus. Other reason, for non-commuter trip, may be people continue their trip to other destination or change their destination as the end-to-end terminal linked by Ipoh-Lumut bus route is open to access other route for the next destination. Therefore, the number is possibly different between two directions.

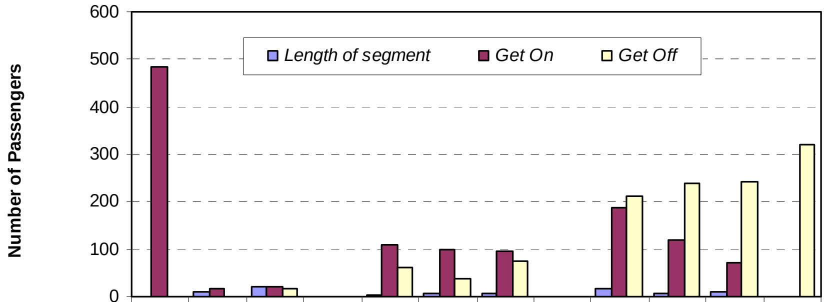
Table 6.5 shows passengers per day by zone. The total trip productivity per day in the corridor is 2,560 passengers per day. Those are distributed into three districts as the following, Kinta (558 get on and 611 get off), Perak Tengah (635 get on and 531 get off) and Manjung (1367 get on and 1418 get off). Those numbers represent the potential demand of bus service. Moreover, Figure 6.4 and Figure 6.5 show the potential and distribution of demand based on data survey over one year.

Table 6.4 Number of passengers per bus per day in Ipoh-Lumut highway

Direction	Trip productivity (pass/bus/day)	
	Get on	Get off
Ipoh to Lumut	172	172
Lumut to Ipoh	194	194
Two way	366	366

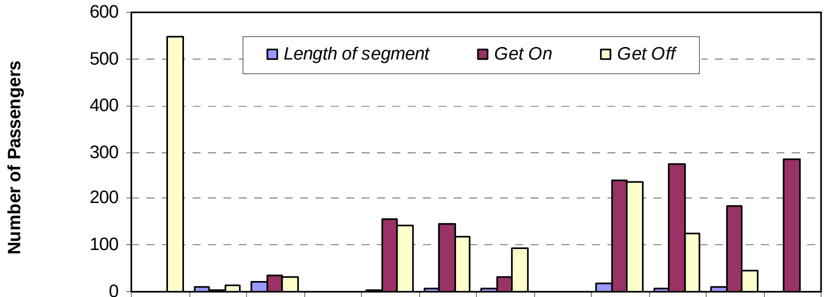
Table 6.5 Passengers per day based on zone

Location	Distance (km)	Ipoh to Lumut		Lumut to Ipoh		Two way	
		Get on	Get off	Get on	Get off	Get on	Get off
1. Kinta							
a. Ipoh bus station	0	483	0	0	548	483	548
b. Menglembu	9.82	16	1	4	15	20	16
c. Pusing-Tronoh	20.18	19	16	36	32	55	47
Sub total =	30	518	17	40	594	558	611
2. Perak Tengah							
a. Bandar Seri Iskandar	4.9	109	61	155	144	264	205
b. Bota Kanan	7.7	98	37	146	119	244	156
c. Bota Kiri	6.8	96	76	31	95	127	171
Sub total =	19.4	304	174	332	357	635	531
3. Manjung							
a. Ayer Tawar	17.1	189	212	241	235	430	446
b. Sitiawan	7.4	120	238	273	125	393	363
c. Manjung	8.7	73	241	186	46	258	287
d. Lumut bus station	0	0	322	286	0	286	322
Sub total =	33.2	382	1012	985	406	1367	1418
Total =	82.6	1,203	1,203	1,357	1,357	2,560	2,560



	Ipoh bus station	Mengle mbu	Pusing-Tronoh		Bandar Seri Iskandar	Bota Kanan	Bota Kiri		Ayer Tawar	Sitiawan	Manjung	Lumut bus station
Length of segment	0	9.82	20.18		4.9	7.7	6.8		17.1	7.4	8.7	0
Get On	483	16	19		109	98	96		189	120	73	0
Get Off	0	1	16		61	37	76		212	238	241	322

Figure 6.4 Number of passengers per day by zone in Ipoh-Lumut direction



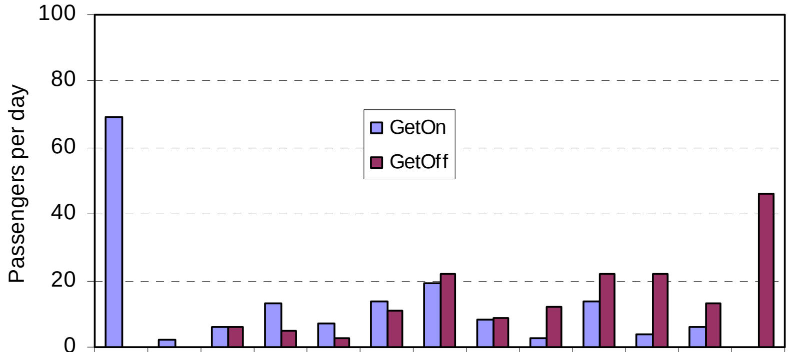
	Ipoh bus station	Mengle mbu	Pusing-Tronoh		Bandar Seri Iskandar	Bota Kanan	Bota Kiri		Ayer Tawar	Sitiawan	Manjung	Lumut bus station
Length of segment	0	9.82	20.18		4.9	7.7	6.8		17.1	7.4	8.7	0
Get On	0	4	36		155	146	31		241	273	186	286
Get Off	548	15	32		144	119	95		235	125	46	0

Figure 6.5 Number of passengers per day by zone in Lumut-Ipoh direction

The graph in Figure 6.6 shows the results of an experiment to investigate the relationship between the percentage of passengers and stationing traveled by bus from Ipoh to Lumut bus station. The percentage of passengers is calculated for indicating location or station with various level of generating or attracting of passengers form Ipoh (km 0) to Lumut (km 82.6). The blue legend is a symbol for the percentage of passengers getting on bus and the black one is a symbol for those who getting off bus.

The percentage of passengers getting on bus at Ipoh bus station (km 0) is equal to 40% and those of getting off bus is 0%. In other place, at the end terminal (Lumut bus station), the percentage of passengers getting on bus at the station (km 82.6) is equal to 27% and those of get off bus is 0%. Figure 6.7 also shows that, in Lumut to Ipoh direction, Lumut bus station has 21% passengers getting on bus. Meanwhile, Ipoh bus station has 40% passengers getting off.

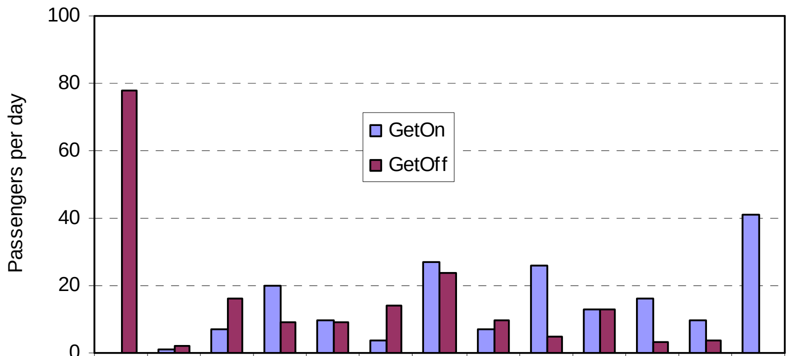
Based on the phenomena mentioned above, those absolutely show that Ipoh and Lumut bus stations are both still being the main start-end terminal in this Ipoh-Lumut bus route. In addition, it might also possible to consider that other stations have been reaching the more attractive and generative locations. For instance, Ayer Tawar, Sitiawan and Taman Maju (Bandar Seri Iskandar) are now becoming great town with high growth socio-economics development.



	0	9.8	30.2	34.9	415	49.4	59.1	66.5	71	73.9	75.3	814	82.6
	Ipoh		Taman M		Bota Ka		Ayer T		Sitiawan		Manjung		Lumut
GetOn	69	2	6	13	7	14	19	8	3	14	4	6	0
GetOff	0	0	6	5	3	11	22	9	12	22	22	13	46

Stationing (km)

Figure 6.6 Number of passengers along the route in Ipoh-Lumut direction



	0	9.8	30.2	34.9	415	49.4	59.1	66.5	71	73.9	75.3	814	82.6
	Ipoh		Taman M		Bota Ka		Ayer T		Sitiawan		Manjung		Lumut
GetOn	0	1	7	20	10	4	27	7	26	13	16	10	41
GetOff	78	2	16	9	9	14	24	10	5	13	3	4	0

Stationing (km)

Figure 6.7 Number of passengers along the route in Lumut-Ipoh direction

Figure 6.8 shows that, for two-way trip, there are top three stations which have both attractive and generative passengers per day such as Ipoh bus station, Ayer Tawar and Lumut bus station. These facts are indicated by the number of passengers getting on and getting off bus at the station and around. In the facts, the three locations are all having high socio-economic activities which deriving high mobility of people demanding transportation facilities. In descending sequence of level of socio-economic activities, those locations are Ipoh bus station, Ayer Tawar and Lumut bus station.

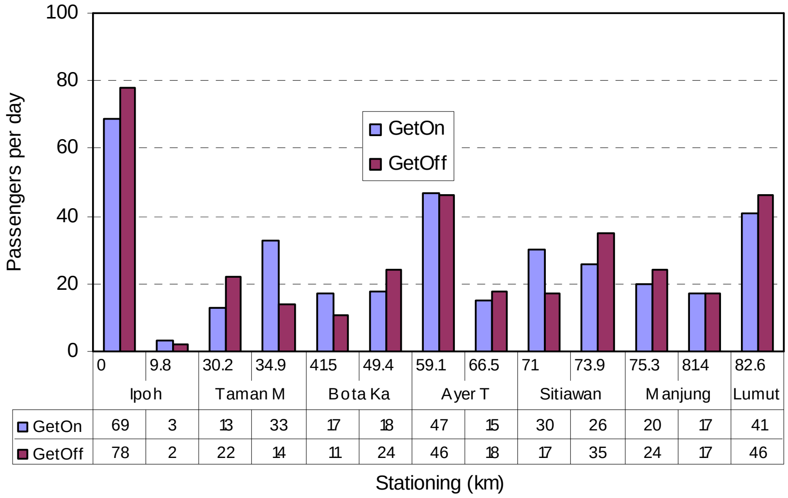


Figure 6.8 Number of passengers along the route for two way trip

6.1.3 Time-Based Demand of Bus Service

Figure 6.9 to Figure 6.11 show the trip productivity and load factor for one day, one week and one year survey period. Trip productivity in mid-day period (11:00-15:00) is the highest. Therefore, the one week and one year survey was performed by referring to that period.

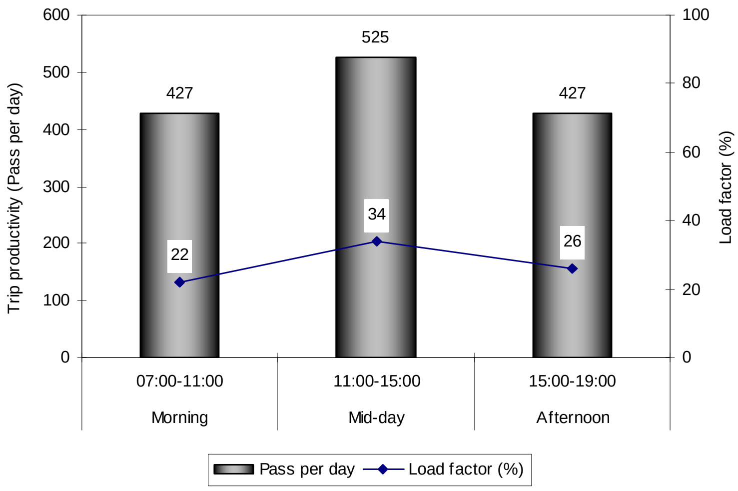


Figure 6.9 Trip productivity and load factor one day, 24 January 2007

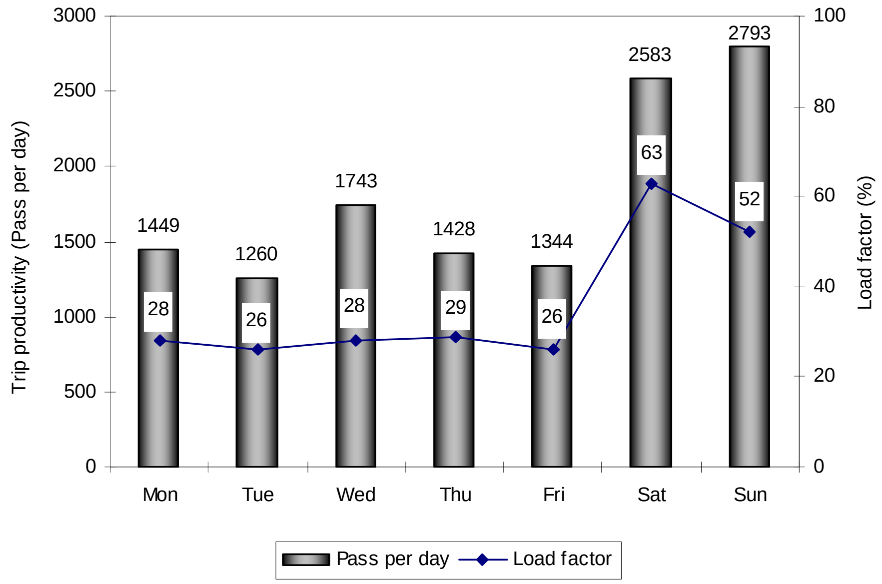


Figure 6.10 Trip productivity and load factor one week, 12–18 February 2007

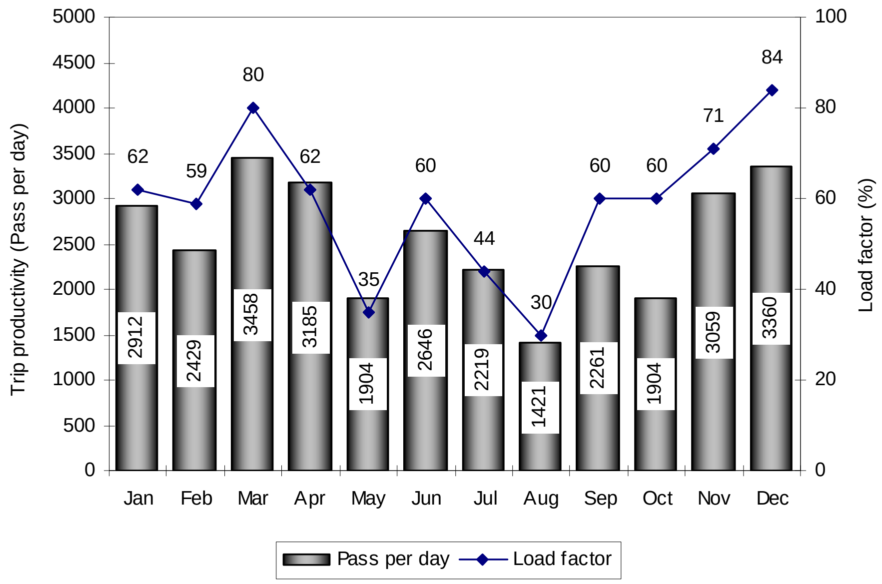


Figure 6.11 Trip productivity and load factor each month in 2007

6.2 Alternative of Bus Service Improvement

Based on the demand of bus service which is categorized into spatial-based and time-based demand as explained in previous sections, then the strategic operation planning to improve the bus service with respect to those consideration are as follow:

1. Spatial-based strategic operation planning

a. bus stop upgrading and relocation
b. providing adequate bus bay and shelter facility
c. develop accessibility of bus service

2. Time-based strategic operation planning
    a. bus priority system with aims to reduce the traffic level, for example, bus priority at signalized junction
    b. bus travel time management, for example, by applying GPS in vehicle
    c. redesign or adjustment of time table

In accordance to the strategy above and in order to attract and to promote more passengers using bus service (ridership), it can be performed by improving the quality of bus service. The procedure of calculation and analysis to improve quality of service are explained as below.

6.2.1 Strategy on the Change of Service Frequency

This strategy to change frequency with objective is to attract more increased demand or ridership.

a) <u>Existing case</u>

The existing bus service data is given,

Total service hour is 14 hours (from 07:00 to 21:00)

Cycle time (*CT*) = 258 minute (observed) but 4 hour (from timetable)

Number of passenger (*P*) = 3,927 passenger per day (observed)

Load factor (*LF*) = 59% (observed)

Capacity of bus (*C*) = 44 seats (given)

The calculation is as the following,

Headway (*H*), $H = \frac{60 \times C \times LF}{P} = \frac{60 \times 44 \times 59}{3927}$ = 39.66 minutes

Frequency (*F*), $F = \frac{1}{H}$ = 1.5 bus/hour = 3 bus per 2 hours

As the availability of vehicle is 100%, then $F_v = 1$, therefore

Number of bus (*K*), $K = \frac{CT}{H \times Fv} = \frac{258}{39.66 \times 1}$ = 6.51 ≈ 7 buses per day

There are 3 round trips per bus each day. Therefore, there are 21 buses per day.

Checked for the load factor as

$$LF = \frac{H \times P}{60 \times C} = \frac{CT \times P}{60 \times C \times K} = \frac{258 \times 3927}{60 \times 44 \times 7} = 54.825 \approx 55\ \% \text{ (less than 59\%)}$$

b) Alternative 1 – set headway = 30 minutes

Data given,

Number of passenger (P) = 4,030 passenger per day (estimated)

Frequency (F) $F = \frac{1}{H}$ = 2 bus/hour

As the availability of vehicle is 100%, then F_v = 1, therefore

Number of bus (K), $K = \frac{CT}{H \times Fv} = \frac{258}{30 \times 1}$ = 8.6 ≈ 9 buses per day

For planning, the required number of bus ideally (spare fleet of 10%) is 9 x 1.1 = 10 bus per day. There are 3 round trips per bus each day. Therefore, there are 30 buses per day.

Checked for the load factor as

$$LF = \frac{H \times P}{60 \times C} = \frac{CT \times P}{60 \times C \times K} = \frac{258 \times 4030}{60 \times 44 \times 10} = 39.384 \approx 40\ \% \text{ (less than 59\%)}$$

c) Alternative 2 – set headway = 20 minutes

Data given,

Number of passenger (P) = 4,030 passenger per day (estimated)

Frequency (F) $F = \frac{1}{H}$ = 3 bus/hour

As the availability of vehicle is 100%, then F_v = 1, therefore

Number of bus (K), $K = \frac{CT}{H \times Fv} = \frac{258}{20 \times 1}$ = 12.9 ≈ 13 buses per day

For planning, the required number of bus ideally (spare fleet of 10%) is 13 x 1.1 = 14 bus per day. There are 3 round trips per bus each day. Therefore, there are 42 buses per day.

Checked for the load factor as

$$LF = \frac{H \times P}{60 \times C} = \frac{CT \times P}{60 \times C \times K} = \frac{258 \times 4030}{60 \times 44 \times 15} = 26.256 \approx 27\ \% \text{ (less than 59\%)}$$

Table 6.6 Summary of analysis on change of service frequency

Scenario	Headway, H (minute)	Capacity, C (seats)	Frequency, F (bus/hour)	Number of bus per day, K (bus per day)	Load factor, LF (%)	Roundtrips per day (bus trip)
Existing service	39.66	44	3 bus/2-hours	7	59	21
Alternative 1	30	44	2 bus/hour	10	40	30
Alternative 2	20	44	3 bus/hour	14	28	42

Table 6.7 Analysis of scenario on frequency change

Strategy	Scenario description
Existing service	Remain to apply the existing condition of bus service
Alternative 1	1. Using the same capacity of bus with 25 seats 2. The frequency, 2 bus/hour, is uniform at peak and of peak session with headway of about 30 minute 3. Suitable for short-term 4. The number of buses is necessary to be added 5. LF actual is possible to increase due to shorter headway of about 30 minute 6. Capital cost increase (↑) and also operation & maintenance (↑), because high frequency of service
Alternative 2	1. Using large bus with capacity of 44 seats 2. Short headway 20 minute is applied with frequency of about 3 buses/hour 3. Suitable for short-term to long–term planning 4. The number of buses is necessary to be added 5. For a short time, load factor (LF) may decrease, but after users being familiar and attracted with new frequency, the LF will potentially increase 6. Capital cost increase (↑) by adding facility and also the operation & maintenance cost will increase (↑↑)

6.2.2 Strategy on the Change of Service Capacity

This strategy changes the capacity of bus with objective to overcome the overcrowding demand or ridership. The capacity of bus refers to Table 6.8.

a) <u>Existing case</u>

The existing bus service data is given,

Total service hour is 14 hours (from 07:00 to 21:00)

Capacity of bus (C) = 44 seats (given)

Load factor (LF) = 59% (observed)

Cycle time (CT) = 258 minute (observed) but 4 hour (from timetable)

Number of passenger (P) = 3,927 passenger per day (observed)

The calculation is as the following,

Headway (H), $$H = \frac{60 \times C \times LF}{P} = \frac{60 \times 44 \times 59}{3927} = 39.66 \text{ minutes}$$

Frequency (F), $F = \dfrac{1}{H}$ = 1.5 bus/hour = 3 bus per 2 hours

As the availability of vehicle is 100%, then F_v = 1, therefore

Number of bus (K), $K = \dfrac{CT}{H \times Fv} = \dfrac{258}{39.66 \times 1}$ = 6.51 ≈ 7 buses per day

There are 3 round trips per bus each day. Therefore, there are 21 buses per day.

Checked for the load factor as

$LF = \dfrac{CT \times P}{60 \times C \times K} = \dfrac{258 \times 3927}{60 \times 44 \times 7}$ = 54.825 ≈ 55 % (less than 59%)

Table 6.8 Type of bus and its capacity

Type of bus	Number of seats	Capacity for calculation	Remarks
Mini bus	18-25	25	no standees
Large bus	38-44	44	no standees
		51	(+15% standees)
Double-decker / Articulated bus	44 + 36	80	no standees

b) <u>Alternative 1: use minibus (capacity of 25 seats)</u>

Data given,

Number of passengers (P) = 4,030 passenger per day (estimated)

Load factor (LF), $LF = \dfrac{CT \times P}{60 \times C \times K}$

Number of bus (K), $K = \dfrac{CT \times P}{60 \times C \times LF} = \dfrac{258 \times 4030}{60 \times 25 \times 59}$ = 11.75 buses ≈ 12 buses

Checked,

As the availability of vehicle is 100%, then F_v = 1, therefore

Headway (H), $H = \dfrac{CT}{K \times Fv} = \dfrac{258}{12 \times 1}$ = 21.5 minutes ≈ 20 minutes (applicable)

Frequency (F), $F = \dfrac{1}{H}$ = 3 bus/hour

Number of bus (K), $K = \dfrac{258}{20 \times 1}$ = 12.9 buses ≈ 13 buses (applicable)

For planning, the required number of bus ideally (spare fleet of 10%) is 13 x 1.1 = 14 bus per day. There are 3 round trips per bus during a day (14 hours). Therefore, there are 42 buses per day.

c) <u>Alternative 2: use large bus with capacity of 44+15% (standees allowed) seats</u>

Data given,

Number of passenger (P) = 4,030 passenger per day (estimated)

Capacity of bus (C) = 44 x (1.15) = 51 seats

Load factor (LF), $LF = \dfrac{CT \times P}{60 \times C \times K}$

Number of bus (K), $K = \dfrac{CT \times P}{60 \times C \times LF} = \dfrac{258 \times 4030}{60 \times 51 \times 59}$ = 5.76 buses ≈ 6 buses

Checked,

As the availability of vehicle is 100%, then F_v = 1, therefore

Headway (H), $H = \dfrac{CT}{K \times Fv} = \dfrac{258}{6 \times 1}$ = 43 minutes ≈ 40 minutes (applicable)

Frequency (F), $F = \dfrac{1}{H}$ = 3 bus/2-hour

Number of bus (K), $K = \dfrac{CT}{H \times Fv} = \dfrac{258}{40 \times 1}$ = 6.45 buses ≈ 7 buses (applicable)

For planning, the required number of bus ideally (spare fleet of 10%) is 7 x 1.1 = 8 bus per day. There are 3 round trips per bus during a day (14 hours). Therefore, there are 24 buses per day.

d) <u>Alternative 3: use double decker / articulated bus with capacity of 80 seats</u>

Data given,

Number of passenger (P) = 4,030 passenger per day (estimated)

Load factor (LF), $LF = \dfrac{CT \times P}{60 \times C \times K}$

Number of bus (K), $K = \dfrac{CT \times P}{60 \times C \times LF} = \dfrac{258 \times 4030}{60 \times 80 \times 59}$ = 3.67 buses ≈ 4 buses

Checked,

As the availability of vehicle is 100%, then F_v = 1, therefore

Headway (H), $H = \dfrac{CT}{K \times Fv} = \dfrac{258}{4 \times 1}$ = 64.5 minutes ≈ 60 minutes (applicable)

Frequency (F), $F = \dfrac{1}{H}$ = 1 bus/hour

Number of bus (K), $K = \frac{258}{60 \times 1}$ = 4.3 buses ≈ 5 buses (applicable)

For planning, the required number of bus ideally (spare fleet of 10%) is 5 x 1.1 = 6 bus per day. There are 3 round trips per bus during a day (14 hours). Therefore, there are 18 buses per day.

Table 6.9 contains summary of analysis on the change of service capacity. Choosing the alternative of capacity of bus service gives changes on other parameters as summarized in this table. All alternative of capacity are assessed with the following description as in Table 6.10.

Table 6.9 Summary of analysis on change of service capacity

Scenario	Capacity, C (seats)	Number of bus per day, K (bus per day)	Headway, H (minute)	Frequency, F (bus/hour)	Load factor, LF (%)	Roundtrips per day (bus trip)
Existing service	44	7	39.66	3 bus/2-hours	59	21
Alternative 1	25	14	20	3 bus/hours	59	42
Alternative 2	51	8	40	3 bus/2-hour	59	24
Alternative 3	80	6	60	1 bus/hour	59	18

Table 6.10 Analysis of scenario on capacity change

Strategy	Scenario description
Existing service	Remain to existing condition
Alternative 1	1. Using minibus with capacity of 25 seats 2. It may not be preferred choice due to more expensive in capital cost and operation & maintenance cost 3. For short-term planning is not feasible, but it may be good for long-term planning 4. Load factor (LF) actual is possible to increase due to shorter headway of about 20 minute 5. Capital cost increase (↑) and also operation & maintenance (↑↑), because high frequency of service
Alternative 2	1. Using large bus with allowed standees 2. Adding facility standees passenger such as air condition, hang holder, etc. 3. Fleet isn't changed but required an improvement of facility 4. Suitable for short-term planning 5. LF actual will be possible to decrease due to users do not prefer to use bus because of too crowded (inconvenience) 6. Frequency is still low. 7. Capital cost increase (↑) by adding facility and also the operation & maintenance cost will increase (↑)
Alternative 3	1. Users will not be attracted because headway is very long 2. LF actual will decrease practically due to the increase of passengers is not significant 3. Capital cost increase (↑↑) by adding facility and also the operation & maintenance cost will increase (↑),because high cost to invest it (fleet, road, facility, etc).

6.2.3 Strategy on the Maintaining of Service Reliability

The main factors that unable to maintain bus service reliability discussed in this thesis covers such as on-time performance, service regularity, punctuality index and waiting time. Naturally, the demand of bus service increases when the level of service quality increases. Therefore, the reliability of bus service performance is necessary to be improved for achieving viable and reasonable standard. Those factors are among the reasonable measurements to attract more bus service passengers.

In section 6.3.9, as mentioned in Table 6.29 the reliability factor such as punctuality index, waiting time, regularity and on-time performance is discussed. Analysis of elasticity of those reliability factors to the sensitivity of bus service demand is clearly performed. Their absolute values of elasticity are more than one. These indicate that punctuality index, waiting time, regularity and on-time performance are categories as the elastic factors to the sensitivity of bus service demand.

6.3 Sensitivity of Bus Service Demand

To assess the bus service demand sensitivity, the elasticity is measured. Elasticity of bus service demand E is a useful descriptor for explaining the degree of sensitivity to a change in price or some other factors. Bus service demand is reflected by number of passenger per day.

In this study, the demand sensitivity of bus service is assessed based on the change in factors or travel attributes such as ticket fare, fuel price, per capita income and service frequency. Those factors are compiled from both primary and secondary data collected. Several assumptions and practical estimation method are applied according to the need as mentioned for each ridership factors assessed. The data, assumption, estimation and calculation steps are explained in the following sub section in results and discussion section.

6.3.1 Bus Service Demand and Passenger Growth Rate

For analysis, in general, the use of maximum passengers per day in 2007 is preferable. Thus, Q_{2007} = 3,927 passengers per day (see Table 6.11). In this case, however, the scenario of analysis is divided into three scenarios such as pessimistic, moderate and optimistic for comparison purpose (see Table 6.13). Pessimistic scenario analysis considers the minimum passengers per day which means that people are unenthusiastic to use bus service. Moderate scenario is based on the average number of passengers per day using bus. Meanwhile, optimistic scenario is analysis of demand regarding to the maximum number of passengers per day using bus service.

Table 6.11 Number of passengers per day in 2007

Type	Passengers per bus per day	Passengers per day (Calculated)*
Maximum	561	3,927
Average	366	2,560
Minimum	138	966

Note: *) there are 7 bus/day operated

Table 6.12 shows the number of population and motor vehicle per thousand populations as mentioned in section 4.5.2. The number of vehicles per thousand populations is called service rate. However, the number of vehicles per kilometer (access rate) is not discussed in this section. For approximation, the growth of passengers is predicted by using the growth of population. The equation to calculate growth rate of population is

$$r = \frac{1}{n-1}\sum_{i}^{n-1}\frac{P_{i+n}-P_i}{P_i} \tag{6.1}$$

In general, the number of people trips grow in an area depends on the population growth. Therefore, it is considered that the growth of population is used for assuming the growth of number of bus passengers. The calculation of population growth rate is also indicated in Table 6.12.

Table 6.12 The growth rate of populations and transport indicators

State	Population in 2005 (million)	Service rate			
		Cars/ 1,000 pop	Motor/ 1,000 pop	Tot veh/ 1,000 pop	Bus-taxi-hired cars/ 1,000 pop
Perak - 2004	2.23	189	365	595	3.7
2005	2.26	200	379	621	3.7
2006	2.28	212	394	648	3.7
2007	2.32	217	397	658	3.7
Malaysia - 2004	25.58	231	257	538	5.1
2005	26.13	248	268	567	5.2
2006	26.64	261	280	593	4.9
2007	27.17	273	292	619	5
Perak growth rate	1.3%	5.8%	3.8%	4.4%	0
	0.9%	6.0%	4.0%	4.3%	0
	1.8%	2.4%	0.8%	1.5%	0
Average	**1.3%**	**4.7%**	**2.9%**	**3.4%**	**0**
Malaysia growth rate	2.2%	7.4%	4.3%	5.4%	2.0%
	2.0%	5.2%	4.5%	4.6%	-5.8%
	2.0%	4.6%	4.3%	4.4%	2.0%
Average	**2.0%**	**5.7%**	**4.3%**	**4.8%**	**-0.6%**

Note: By referring equation (6.2), the growth rate of transport indicators is calculated.

Source: Department of Statistics Malaysia (2004-2007) [54, 60-62]

The number of passengers in 2009 is predicted by using (6.3).

$$Q_t = Q_0(1+r)^t \tag{6.2}$$

where, Q_0, Q_t : number of passenger at base and target year

r : growth rate (%)

t : time duration (target year – base year)

The following are the calculation of number of passengers per day by referring the growth rate taken from Table 6.12.

i) assume that passengers trip growth rate is approximately similar to r = 1.3% per year . This growth rate is for total passenger trips including both of public transportation use and private cars.

$Q_{2009} = Q_{2007}(1+1.3\%)^2 = 3{,}927(1+1.3\%)^2 = 4{,}030$ passengers per day

By the same way, number of passenger is calculated for moderate and pessimistic scenario. The results are as follow:

- Optimistic : 4,030 passengers per day
- Moderate : 2,630 passengers per day
- Pessimistic : 992 passengers per day

ii) According to Minister of Transport Malaysia [77], the Malaysia targets to increase the modal share of public transportation in the Klang Valley ranging from 10% to 25% by 2012. Thus, for approach in this case study (Perak, Malaysia), it is assumed that 10% growth rate is concerned to public transportation use and 90% is for private cars use. Thus, r = 10%*1.3% = 0.13% per year.

$Q_{2009} = Q_{2007}(1+0.13\%)^2 = 3{,}927(1+0.13\%)^2$ = 3,937 passengers per day

By the same way, number of passenger is calculated for moderate and pessimistic scenario. The results are as follow:

- Optimistic : 3,937 passengers per day
- Moderate : 2,569 passengers per day
- Pessimistic : 969 passengers per day

Based on calculation above, the scenario of solution to the case on bus service demand is mentioned in Table 6.13.

Table 6.13 The analysis scenario on the bus service demand

Scenario	Type	Passengers per day (2007)	Passengers per day (2009) *	Passengers per day (2009) **
Optimistic	Maximum	3,927	4,030	3,937
Moderate	Average	2,560	2,630	2,569
Pessimistic	Minimum	966	992	969

Note: *) : estimated with r = 1,3% per year

**) : estimated with r = 0.13% per year

6.3.2 Price (Ticket Fare) Elasticity to Bus Service Demand

Price elasticity is calculated in term of ticket fare of existing bus service. Bus service system in the existing corridor carries passenger per day as mentioned in Table 6.13, charging RM 6.50 per ride in 2007. At this corridor, there are 7 bus trips provided every day. The management (operator) raises the rate to RM 8.40 per ride in 2009. The elasticity of bus service demand with respect to price is unknown. Therefore, analysis of price elasticity is made to find what ideas can be offered to the management or operator. Ticket fare of bus service (transit trip) is considered as a price variable. Then, the price elasticity is calculated by using mid-point formula. For this case, the elasticity of price is classified into a direct elasticity.

For analysis, in general, the use of maximum passengers per day in 2007 is preferable. Thus, Q_{2007} = 3,927 passengers per day. But in this case, the scenario of analysis is divided into three scenarios such as pessimistic, moderate and optimistic for comparative analysis (See Table 6.13). Pessimistic scenario analysis considers the minimum passengers per day which means that people are unenthusiastic to use bus service. Moderate scenario is based on the average number of passengers per day using bus. Meanwhile, optimistic scenario is the analysis of demand regarding to the maximum number of passengers per day using bus service.

For example, calculation of price elasticity of bus service demand with r = 1.3% per year is as follows:

a. Shrinkage ratio method:

$$e = \frac{\delta Q / Q}{\delta P / P} = \frac{(Q_2 - Q_1)/Q_1}{(P_2 - P_1)/P_1} = \frac{(4{,}030 - 3{,}927)/3{,}927}{(8.40 - 6.50)/6.50} = 0.089526 = 0.09$$

b. Mid-point formula or arc elasticity:

$$e = \frac{\delta Q / Q}{\delta Q / P} = \frac{(Q_2 - Q_1)/(Q_1 + Q_2)}{(P_2 - P_1)/(P_1 + P_2)} = \frac{(4{,}030 - 3{,}927)/(3{,}927 + 4{,}030)}{(8.40 - 6.50)/(6.50 + 8.40)}$$

$$= 0.1010285 = 0.10$$

c. Log-arc elasticity method:

$$e = \frac{\delta Q / Q}{\delta P / P} = \frac{\log Q_2 - \log Q_1}{\log P_2 - \log P_1} = \frac{\log 4{,}030 - \log 3{,}927}{\log 8.40 - \log 6.50} = 0.100739 = 0.10$$

Similarly, the elasticity of price for bus service demand with r = 0.13% per year is also calculated. The result of price elasticity calculation is shown in Table 6.14. This table indicates that both arc elasticity and log-arc elasticity methods result close values. Therefore, the arc elasticity is generally applied for discussion.

Table 6.14 Price elasticity using three methods

Demand scenario	Transit ridership (pass/day) 2007 (Q_1)	2009 (Q_2)	Price elasticity SHR (E_f)	ARC (E_f)	LOG-ARC (E_f)	Deviation Δ_1	Δ_2	Δ_3
r = 1.3% per year								
Optimistic	3,927	4,030	0.089526	0.101285	0.100739	0.011759	0.011213	0.000546
Moderate	2,560	2,630	0.089526	0.101285	0.100739	0.011759	0.011213	0.000546
Pessimistic	966	992	0.089526	0.101285	0.100739	0.011759	0.011213	0.000546
r = 0.13% per year								
Optimistic	3,927	3,937	0.008901	0.010188	0.010133	0.001288	0.001232	5.55E-05
Moderate	2,560	2,569	0.008901	0.010188	0.010133	0.001288	0.001232	5.55E-05
Pessimistic	966	969	0.008901	0.010188	0.010133	0.001288	0.001232	5.55E-05

Note: E_f = price (ticket fare) elasticity, SHR = shrinkage ratio, ARC = arc elasticity, LOG-ARC = log-arc elasticity. $\Delta_1 = |E_{shr}-E_{arc}|$; $\Delta_2 = |E_{shr} - E_{log\text{-}arc}|$; $\Delta_3 = |E_{arc}-E_{log\text{-}arc}|$

By referring to the population growth, that both transit and private cars demand growth are assumed 1.3%. The elasticity of transit demand with respect to price is not negative. This means that a 1% increasing fare will still lead to a 0.101285% increase in transit demand. This happens because the increasing fare does not affect people leaving from using public transportation. Therefore, the increase in fare from RM 6.50 to RM 8.40 (a 29.2% increase) is not likely to reduce the transit demand in this corridor. The number of 3,927 passengers per day in 2007 will remain to increase to 4,030 in 2009 (a 2.96% increase). In terms of revenue, the results are as follows (see Table 6.15):

3,927 passengers at RM 6.50/ride = RM 25,526

4,030 passengers at RM 8.40/ride = RM 33,851

Thus, the company will still benefit as follow:

- Optimistic = 33,851 – 25,526 = RM 8,325 per day
- Moderate = 22,067 – 16,640 = RM 5,427 per day
- Pessimistic = 8,327 – 6,279 = RM 2,048 per day

Table 6.15 The total revenue based on the price elasticity

Demand scenario	Revenue 2007	2009	Incremental benefit
r = 1.3% per year			
Optimistic	25,526	33,851	8,325
Moderate	16,640	22,067	5,427
Pessimistic	6,279	8,327	2,048
r = 0.13% per year			
Optimistic	25,526	33,073	7,547
Moderate	16,640	21,560	4,920
Pessimistic	6,279	8,136	1,857

Additionally, it is estimated that transit demand grow by 10% of the r = 1.3% of total demand growth. Then, this is called as a low growth rate of passengers. For optimistic scenario, in condition of low growth rate of passengers (r = 0.13%), the price elasticity equal to 0.010188. Here, the company will still benefit of RM 7,547 per day, as the revenue is RM 33,073 per day. In other words, there is no loss in revenue for the company/management due to increase in fare.

In other side, the increasing fare does not practically reduce the people from using bus service. This may due to subsidy allocated by government makes the fare still affordable. The increase of fare is not significant against the passenger's growth. This is shown by positive elasticity.

6.3.3 Kraft Demand Model

General model used for analysis of the change in transit demand with respect to price or other factors is called Kraft Demand model. In this model has constant elasticity with respect to change in price. The equation of model is given,

$$Q = \alpha P^{\beta} \tag{6.3}$$

where, Q is number of passenger trip by using transit (passengers per day), α is the coefficient determined as function of price, β is the elasticity of transit demand with respect to price and P is price. In this case, the elasticity of transit demand with respect to price is β, it means that a 1% increase in transit fare will result in a β decrease in the number of passengers using the system.

Based on the above result, price elasticity, the Kraft Demand model is obtained,

$$Q = \alpha(P)^{\beta} \quad --> \quad Q = 3248.816(P)^{0.101285}$$

In fact, the model has small deviation value of α coefficient as indicated in Table 6.16. In this case, it should be noted that the effect of change in price is not negative as in general case, due to the current situation and the short-term period. At this situation, the change in price is still affordable due to subsidy.

Table 6.16 Estimated parameter of Kraft Demand model

Year	Demand (Q)	Price (P)	Elasticity (E-arc)
2007	3927	6.5	
2009	4030	8.4	0.10128477

Proof 1 $3927 = \alpha_1 * (6.5)^{0.10128477}$

$\alpha =$ 3248.816

Proof 2 $4030 = \alpha_2 * (8.4)^{0.10128477}$

$\alpha =$ 3248.362

Deviation, $|\alpha_1-\alpha_2| = 0.45465$

Note: E-arc = arc-elasticity or mid-point formula

6.3.4 Fuel Price Elasticity to Bus Service Demand

The effect of change in the price of goods on the demand for the same goods is referred to as direct elasticity. However, the measure of responsiveness of demand for goods to the price of other goods is referred to as cross elasticity. Two things are substitute goods if their cross elasticity is positive. For example, bus and gas are substitute goods, their cross elasticity is positive. Otherwise, for example, bus and airplane are complement goods, thus, the cross elasticity is negative. Below is the calculation of fuel price elasticity which affects the change in demand of bus service.

For the case of Ipoh-Lumut corridor, a 20% increase in fuel costs (from RM 1.60 per liter in 2007 to RM 1.92 per liter in 2009) has resulted in a 2.62% increase in bus patronage (from 3,927 passengers per day in 2007 to 4,030 passenger per day in 2009). Then, calculation is needed for the implied cross elasticity of demand.

For the calculation, let

P_0 : price of fuel before = RM 1.60

P_1 : price of fuel after = RM 1.92 } There is a 20% increase

B_0 : bus patronage before = 3,927 passengers/day

B_1 : bus patronage after = 4,030 passengers/day } a 2.62% increase

The cross elasticity of fuel price is calculated as follows:

Bus: $B_1 = B_0+0.0262B_0 = (1+0.0262)B_0$

Fuel: $P_1 = P_0+0.20P_0 = (1+0.20)P_0$

$B = B_0+1.0262B_0 = (1+1.0262)B_0$

$dB = B_1-B_0 = 1.0262B_0 - B_0 = 0.0262B_0$

$dB/B = 0.0262 /(1+1.0262)$

$P = P_0+1.20P_0 = (1+1.20)P_0$

$dP = P_1\text{-}P_0 = 1.20P_0 - P_0 = 0.20P_0$

$dP/P = 0.20 / (1+1.20)$

$E = (dB/B)/(dP/P) = [0.\ 0262/(1+1.0262)] / [0.20/(1+1.20)] = +0.142$

Hence, $E = +0.142$

The cross elasticity is mentioned in Table 6.17 below.

Table 6.17 Fuel price elasticity using three methods

Demand scenario	Fuel price elasticity		
	SHR (E_{fp})	ARC (E_{fp})	LOG-ARC (E_{fp})
r = 1.3% per year			
Optimistic	0.130845	0.142071	0.141686
Moderate	0.130845	0.142071	0.141686
Pessimistic	0.130845	0.142071	0.141686
r = 0.13% per year			
Optimistic	0.013008	0.014291	0.014251
Moderate	0.013008	0.014291	0.014251
Pessimistic	0.013008	0.014291	0.014251

Note: E_{fp} = fuel price elasticity

6.3.5 Income Elasticity to Bus Service Demand

The percentage of income based on the income category or income distribution data for Kinta and Manjung is not available (See section 4.2.2). Meanwhile, data for Perak Tengah is only in 2000. Regarding the development of city, Kinta and Manjung districts might have different distribution from Perak Tengah. Because the detail of income was not completely gained from the sources, then other socio-economic data is used for the approach of analysis. Series data of per capita GDP as indicated in Table 6.18 is used for the approach of analysis. The per capita GDP of Perak increase 81% (RM 9,322.07) from RM 11,476.64 (1998) to RM 20,798.71 (2007). From 1998 to 2007, the average GDP is RM 15,884.63 per year with increasing rate of 6.8%. Compare to whole Malaysia, during 1998 to 2007, the average GDP is RM 16,930.07 per year with increasing rate of 5.8%.

Table 6.18 Per capita GDP of Perak and whole Malaysia

Year	Perak		Malaysia	
	Private motor cars per 1,000 population	Per capita Gross Domestic Product	Private motor cars per 1,000 population	Per capita Gross Domestic Product
	y=Car	x=GDP	y=Car	x=GDP
1998	136.87	11,476.64	157.37	12,919.65
1999	145.26	12,314.44	167.60	13,733.58
2000	154.67	13,183.00	178.13	14,584.00
2001	161.01	14,118.99	189.81	15,400.70
2002	170.80	15,121.44	203.91	16,263.14
2003	179.20	16,195.06	216.73	17,173.88
2004	189.14	17,344.91	231.10	18,135.62
2005	200.38	18,616.00	247.75	19,189.00
2006	211.75	19,677.11	260.58	20,340.34
2007	217.37	20,798.71	273.08	21,560.76
Average	176.65	15,884.63	212.61	16,930.07
Growth rate	5.28%	6.83%	6.32%	5.86%

Note: y : number of private motor cars per 1,000 population

x : GDP (per capita Gross Domestic Product)

Source: Department of Statistics, Malaysia [60-62]

Table 6.19 The income growth of Perak and whole Malaysia

Year	Perak		Malaysia	
	Per capita GDP	Growth (r = 6.83%)	Per capita GDP	Growth (r = 5.86%)
2007	20,798.71	Base year	21,560.76	Base year
2008	22,219.53	Predicted	22,823.28	Predicted
2009	23,737.41	Predicted	24,159.72	Predicted
2010	25,358.98	Predicted	25,574.42	Predicted
2015	35,287.75	Predicted	33,991.90	Predicted

Calculation of elasticity of demand to income is shown as below. Let data given,

I_0 : per capita income at 2007 = RM 20,798.71

I_1 : per capita income at 2009 = RM 23,737.41 } a 14.13% increase

B_0 : bus patronage before = 3,927 passengers/day

B_1 : bus patronage after = 4,030 passengers/day } a 2.62% increase

The following is the example of calculation of cross elasticity. This is classified as a direct elasticity.

Bus: $B_1 = B_0+0.0262B_0 = (1+0.0262)B_0$

Income: $I_1 = I_0+0.1413I_0 = (1+0.1413)I_0$

$B = B_0+1.0262B_0 = (1+1.0262)B_0$

$dB = B_1\text{-}B_0 = 1.0262B_0 – B_0 = 0.0262B_0$

$dB/B = 0.0262\ /(1+1.0262)$

$I = I_0+1.1413I_0 = (1+1.1413)I_0$

$dI = I_1\text{-}I_0 = 1.1413I_0 - I_0 = 0.1413I_0$

$dI/I = 0.1413\ /\ (1+1.1413)$

$E = (dB/B)/(dI/I) = [0.0262/(1+1.0262)]/[0.1413/(1+1.1413)] = +0.196$

Hence, $E = +0.196$

The cross elasticity (E_i) is indicated in Table 6.20. The demand will increase about 0.196% as the income (per capita) increase about 1%.

Table 6.20 Income elasticity using three methods

Demand scenario	Income elasticity SHR (E_i)	ARC (E_i)	LOG-ARC (E_i)
r = 1.3% per year			
Optimistic	0.185212	0.195735	0.195462
Moderate	0.185212	0.195735	0.195462
Pessimistic	0.185212	0.195735	0.195462
r = 0.13% per year			
Optimistic	0.018414	0.019689	0.01966
Moderate	0.018414	0.019689	0.01966
Pessimistic	0.018414	0.019689	0.01966

Note: E_i = income elasticity

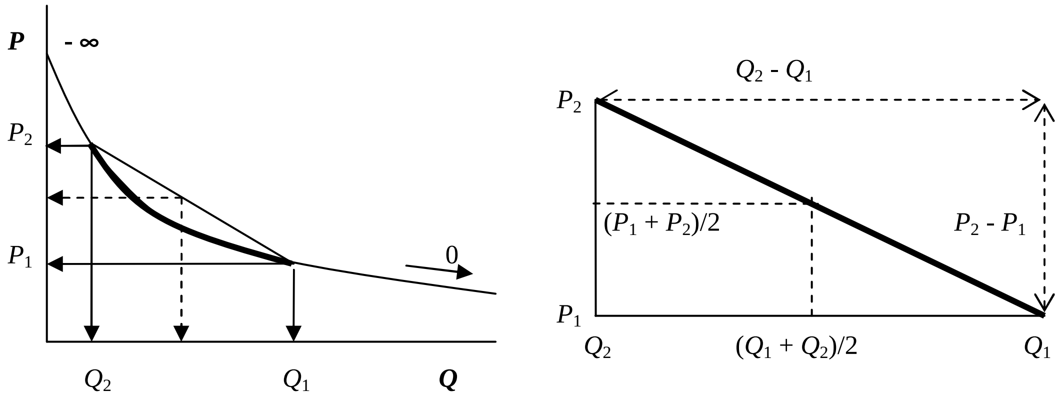
6.3.6 Elasticity of Frequency Change

The scheme of frequency change is taken from the analysis of strategy for improvement of bus service quality (See section 6.2.1). In this case, frequency change aims to produce the attractive waiting time rather than to relieve the overcrowding demand. The change in number of passengers per day is measured with respect to frequency change. To calculate frequency elasticity, the data and estimated demand are given in Table 6.21. Two alternatives of frequency change are appraised. This analysis assumes the capacity of bus is still remain at the target year. This is classified as a direct elasticity.

Table 6.21 Scheme of number of passengers with respect to frequency change

Scenario	Description	Headway, H (minute)	Frequency, F (bus/hour)	Roundtrips per day (bus trip)	Number of passengers per day, P (pass/day)
Existing service	2007	39.66	3 bus/2-hours	21	3,927
Alternative 1	2009	30	2 bus/hour	30	4,030
Alternative 2	2009	20	3 bus/hour	45	4,030

The calculation of elasticity by using the mid-point elasticity formula is as follows:



Note: $-\infty$ = perfectly elastic, 0 = perfectly inelastic, -1 = change in demand equals change in "price". The elasticity β means that every 1% of price change lost β% ridership.

Figure 6.12 The illustration of elasticity formula

Mid-point elasticity formula:

$$e_p = \frac{(Q_2 - Q_1)}{[(Q_1 + Q_2)/2]} \div \frac{(P_2 - P_1)}{[(P_1 + P_2)/2]} = \frac{(Q_2 - Q_1)(P_1 + P_2)}{(Q_1 + Q_2)(P_2 - P_1)} \tag{6.4}$$

Where, P_1 : price before Q_1 : ridership before
P_2 : price after Q_2 : ridership after

In this case, similarly, the price is replaced with frequency of bus service. Hence,

$$e_f = \frac{(Q_2 - Q_1)}{[(Q_1 + Q_2)/2]} \div \frac{(F_2 - F_1)}{[(F_1 + F_2)/2]} = \frac{(Q_2 - Q_1)(F_1 + F_2)}{(Q_1 + Q_2)(F_2 - F_1)} \tag{6.5}$$

The existing frequency is 3 bus/2-hour or 21 roundtrips per day.

For alternative 1, F_2 = 2 bus/hour, there are 30 roundtrips per day. Hence,

$$e_f = \frac{(Q_2 - Q_1)(F_1 + F_2)}{(Q_1 + Q_2)(F_2 - F_1)} = \frac{(4030 - 3927)(21 + 30)}{(3927 + 4030)(30 - 21)} = \frac{103 \times 51}{7957 \times 9} = 0.073 \approx 7.3\%$$

For alternative 2, F_2 = 3 bus/hour, there are 45 roundtrips per day. Hence,

$$e_f = \frac{(Q_2 - Q_1)(F_1 + F_2)}{(Q_1 + Q_2)(F_2 - F_1)} = \frac{(4030 - 3927)(21 + 45)}{(3927 + 4030)(45 - 21)} = \frac{103 \times 66}{7957 \times 24} = 0.036 \approx 3.6\%$$

The frequency elasticity is summarized as in Table 6.22. Frequency elasticity is necessary to evaluate the change in transportation demand. Normally, the increase in bus service demand can be resulted from the increase in frequency of bus service. Generally, the elasticity of frequency is positive (E_{fr} > 0). For this case, frequency elasticity E_{fr} = 0.035518 (alternative 2) is less than E_{fr} = 0.073188 (alternative 1), however, both are inelastic. At the beginning of improvement (by adding frequency), the load factor still low about 27%, but it is possible to go up after people being familiar with the bus service system and new generated passengers are attracted to use bus. Frequency elasticity of 0.036 means the frequency rise of 1% will result 0.036% increase in bus service demand (ridership). In other words, for approximation, because headway is inverse frequency, therefore, 1% decrease in headway will increase 0.036% increase in transit demand.

Table 6.22 Frequency elasticity using three methods

Demand scenario	Transit ridership (pass/day)		Frequency elasticity Alternative 1			Frequency elasticity Alternative 2		
	2007 (Q_1)	2009 (Q_2)	SHR (E_{fr})	ARC (E_{fr})	LOG-ARC (E_{fr})	SHR (E_{fr})	ARC (E_{fr})	LOG-ARC (E_{fr})
r = 1.3% per year								
Optimistic	3,927	4,030	0.061061	0.073188	0.072426	0.022898	0.035518	0.033895
Moderate	2,560	2,630	0.061061	0.073188	0.072426	0.022898	0.035518	0.033895
Pessimistic	966	992	0.061061	0.073188	0.072426	0.022898	0.035518	0.033895
r = 0.13% per year								
Optimistic	3,927	3,937	0.006071	0.007362	0.007285	0.002276	0.003573	0.003409
Moderate	2,560	2,569	0.006071	0.007362	0.007285	0.002276	0.003573	0.003409
Pessimistic	966	969	0.006071	0.007362	0.007285	0.002276	0.003573	0.003409

Note: E_{fr} = frequency elasticity

The frequency elasticity for both alternative 1 and 2 is comparatively shown. Figure 6.13 shows the frequency elasticity on affecting the change in demand. In alternative 1, the 1% increase in frequency will affect the 0.073% increase in demand. Meanwhile, in alternative 2 with higher frequency change, the frequency elasticity is lower, that is at 0.036.

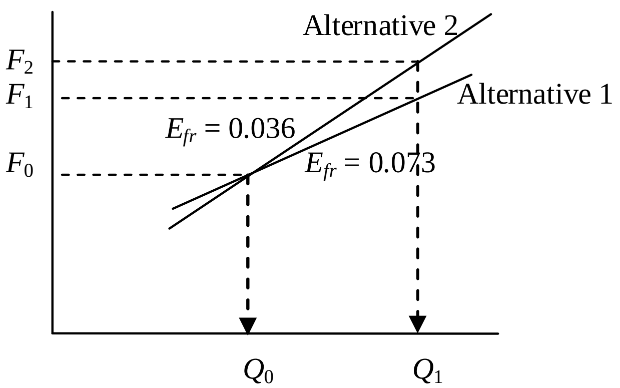


Figure 6.13 The illustration on elasticity of frequency change

6.3.7 Elasticity of Headway Change

Headway is inversely proportional with service frequency. The headway elasticity (*Eh*) is calculated similarly with the way how frequency elasticity is calculated. Headway elasticity is obtained as a direct elasticity. The calculation is made by using mid-point formula based on the data indicated in Table 6.21 above. The result is tabulated in In this case, for alternative 1, as the headway elasticity is -0.09314, the headway change from 39.66 to 30 minute (24.36%) will cause the 2.26% increase in bus service demand. Moreover, in alternative 2, if headway decreases from 39.66 to 20 minute (49.57%), then the demand increases by headway elasticity of -0.03919. Negative sign of headway elasticity means the relative decrease in headway will cause the relative increase in demand.

Table 6.23 Headway elasticity using three methods

Demand scenario	Transit ridership (pass/day)		Headway elasticity Alternative 1			Headway elasticity Alternative 2		
	2007 (Q_1)	2009 (Q_2)	SHR (E_h)	ARC (E_h)	LOG-ARC (E_h)	SHR (E_h)	ARC (E_h)	LOG-ARC (E_h)
r = 1.3% per year								
Optimistic	3,927	4,030	-0.10744	-0.09314	-0.09254	-0.05279	-0.03919	-0.03773
Moderate	2,560	2,630	-0.10744	-0.09314	-0.09254	-0.05279	-0.03919	-0.03773
Pessimistic	966	992	-0.10744	-0.09314	-0.09254	-0.05279	-0.03919	-0.03773
r = 0.13% per year								
Optimistic	3,927	3,937	-0.01068	-0.00937	-0.00931	-0.00525	-0.00394	-0.0038
Moderate	2,560	2,569	-0.01068	-0.00937	-0.00931	-0.00525	-0.00394	-0.0038
Pessimistic	966	969	-0.01068	-0.00937	-0.00931	-0.00525	-0.00394	-0.0038

Note: E_h = headway elasticity

6.3.8 Elasticity of Bus Service Characteristics and Reliability

Other characteristics and reliability of bus service which being evaluated regarding to the elasticity are travel time, punctuality, waiting time, regularity and on-time performance.

a. <u>Travel time</u>

Travel time elasticity is calculated based on the short-run changes in travel time and passenger per day at the first and second semester of 2007. This is classified into a direct elasticity. Table 6.24 indicates that the travel time elasticity significantly exists. In this case, bus service demand changes sensitively with respect to relative change in travel time. This shows that approximately 1% increase in travel time causes 4.057%

decrease in passenger per day. It means that, the reduction of travel time from 240 minute to 216 minute may cause the addition of 1,039 passengers per day from 2,560 to 3,599 passengers per day.

Table 6.24 Travel time elasticity using three methods

Typical or session	Passengers per day (pass/day)		Travel time (minute)		Travel time elasticity		
	Jan-Jun 2007 (Q_1)	Jul-Dec 2007 (Q_2)	Jan-Jun 2007 (T_1)	Jul-Dec 2007 (T_2)	SHR (E_t)	ARC (E_t)	LOG-ARC (E_t)
Overall	2630	2489	237.17	240.42	-3.921342	-4.057220	-4.058188

Note: E_t = travel time elasticity

b. Punctuality Index

Punctuality elasticity, a direct elasticity, is calculated based on the short-run changes in punctuality index and passenger per day at the first and second semester of 2007 as indicated in Table 6.25. Punctuality elasticity describes the sensitivity of bus service demand with respect to the change in punctuality index. For 30 minute headway, it is revealed that 1% increase in punctuality causes 0.883546% increase in passenger per day of bus service and namely inelastic. In other words, the 10% increase in punctuality will affect the 9% increase in passenger per day of bus service. At 60 minute headway, the bus service demand is more sensitive than that of at 30 minute headway. At 60 minute headway, 4.4% increase in passengers per day is due to 1% increase in punctuality and namely elastic.

Table 6.25 Punctuality index elasticity using three methods

Typical or session	Passengers per day (pass/day)		Punctuality index (%)		Punctuality elasticity		
	Jan-Jun 2007 (Q_1)	Jul-Dec 2007 (Q_2)	Jan-Jun 2007 (PI_1)	Jul-Dec 2007 (PI_2)	SHR (E_{pi})	ARC (E_{pi})	LOG-ARC (E_{pi})
Peak (H30)	2630	2489	77.95	73.22	0.886675	0.883546	0.883483
Off peak (H60)	2630	2489	94.49	93.31	4.299346	4.390440	4.391498
				Average:	2.593010	2.636993	2.637491

Note: E_{pi} = travel time elasticity

c. Waiting time

Waiting time elasticity is called a direct elasticity. The calculation is mentioned in Table 6.26. Both at 30 minute and 60 minute headway, the elasticity of waiting time are less than -1, meaning that waiting time is categorized as elastic. At 60 minute headway, bus service demand is more sensitive compared to that of at 30 minute headway. During peak period, 10% decrease in waiting time causes 14% increase in passengers per day. In this case, for example, if waiting time changes from 30 minute to 27 minute than 358 passengers per day may be attracted. Thus, bus service demand increases from 2,560 to 2,918 passengers per day.

Table 6.26 Waiting time elasticity using three methods

Typical or session	Passengers per day (pass/day)		Waiting time (minute)		Waiting time elasticity		
	Jan-Jun 2007 (Q_1)	Jul-Dec 2007 (Q_2)	Jan-Jun 2007 (Wt_1)	Jul-Dec 2007 (Wt_2)	SHR (E_{wt})	ARC (E_{wt})	LOG-ARC (E_{wt})
Peak (H30)	2630	2489	18.31	19.02	-1.388439	-1.454383	-1.454578
Off peak (H60)	2630	2489	31.65	32.01	-4.801109	-4.961276	-4.962486
				Average:	-3.094774	-3.207830	-3.208532

Note: E_{wt} = travel time elasticity

d. Regularity and on-time performance

Table 6.27 contains elasticity of bus service regularity. Regularity elasticity is direct elasticity and the elasticity of regularity is categorized into inelastic. It is assumed to be approximately 10% of scheduled interval after departure time for determination of whether a bus departure is on-time or late [29]. However, it is for city bus service. Hence, for the case of intercity (rural) bus service, the accepted interval for departure regularity is modified approximately 20% of schedule. For instance, regularity interval is within ±15 minute interval and the on-time performance is 0-15 minute. Within ±15 minute interval, the 4.6% increase in passengers per day may due to 1% decrease in regularity. Meanwhile, for the on-time performance, the 1% increase in on-time performance affects 1.15% increase in passenger per day.

Table 6.27 Regularity elasticity using three methods

Typical or session	Passengers per day (pass/day)		Regularity (% passing)		Elasticity regularity		
	Jan-Jun 2007 (Q_1)	Jul-Dec 2007 (Q_2)	Jan-Jun 2007 (Reg_1)	Jul-Dec 2007 (Reg_2)	SHR (E_{reg})	ARC (E_{reg})	LOG-ARC (E_{reg})
Within ±15 minute interval	2630	2489	69.13	68.31	4.526216	4.623574	4.624694

Note: E_{reg} = regularity elasticity

Table 6.28 On-time performance elasticity using three methods

Typical or session	Passengers per day (pass/day)		On-time performance (% passing)		On-time performance regularity		
	Jan-Jun 2007 (Q_1)	Jul-Dec 2007 (Q_2)	Jan-Jun 2007 (Op_1)	Jul-Dec 2007 (Op_2)	SHR (E_{op})	ARC (E_{op})	LOG-ARC (E_{op})
0-15 minute interval	2630	2489	53.85	51.33	1.145918	1.149947	1.150018

Note: E_{op} = on-time performance elasticity

6.3.9 Discussion and Strategic Bus Service Improvement

As in Table 6.29 it is summarized the elasticity of bus service demand with respect to change in some factors. As briefly explained above, the elasticity of transit demand is assessed with respect to ticket fare, fuel price, per capita income, service frequency, headway and travel time. The elasticity of transit demand with respect to price is not negative. The 1% increasing fare will still lead to a 0.10% increase in passenger per day. This is because the increasing fare does not cause people leaving from using public transportation. The increase in fare from RM 6.50 to RM 8.40 (a 29.2% increase) doesn’t reduce the transit use in this corridor. However, a number of 3,927 passengers per day in 2007 still increase to 4,030 in 2009 (a 2.62% increase). In terms of revenue, the benefits are as follows, RM 8,326.50 per day (optimistic scenario), RM 5,439 per day (moderate scenario) and RM 2,054 per day (pessimistic scenario). In other words, there is no loss in revenue for the company/management due to increase in fare.

The increase of fare is still affordable by users as there is subsidy from government, so that it doesn’t significantly influence the demand of bus service. The magnitude of price (ticket fare) change does not make a difference in number passengers. The ticket fare change in two years (2007-2009) is only a single elasticity. However, the elasticity is only relative measure which may still hide various responses. This ticket fare elasticity can be quite different in the short-term plan againts long-term plan.

Table 6.29 Summary of elasticity of bus service demand

Factors	Elasticity	Sign	Type of elasticity	Product or service type	Category of sensitivity
i. <u>Service characteristics:</u>					
a. Ticket fare	0.101285	(+)	direct elasticity	complement	inelastic
b. Fuel price	0.142071	(+)	cross elasticity	substitute	inelastic
c. Income	0.195735	(+)	cross elasticity	complement	inelastic
d. Frequency	0.073188	(+)	direct elasticity	complement	inelastic
e. Headway	-0.093136	(-)	direct elasticity	complement	inelastic
f. Travel time	-4.057220	(-)	direct elasticity	complement	elastic
ii. <u>Reliability:</u>					
a. Punctuality	2.636993	(+)	direct elasticity	complement	elastic
b. Waiting time	-3.207830	(-)	direct elasticity	complement	elastic
c. Regularity	4.623574	(+)	direct elasticity	complement	elastic
d. On-time performance	1.149947	(+)	direct elasticity	complement	elastic

Note: $E = -\infty$: perfectly elastic; $E > -1$: inelastic region
$E = -1$: unit elastic point; $E < -1$: elastic region
$E = 0$: perfectly inelastic

As comparison, the study by VTPI [78, 79] reveals the elasticity for short-term impacts analysis. The elasticity values are lower than those of prediction in medium and long-term changes under conditions in most North American urban areas. The facts, the elasticity of transit ridership with respect to fares is about –0.3 to –0.5 in the short run (first year) and increases to about –0.6 to –0.9 over the long run (five to ten years). Table 6.30 summarizes transit elasticity values.

Table 6.30 Transit elasticity value by others

Aspects	Market Segment	Short Term	Long Term
Transit ridership WRT transit fares	Overall	–0.2 to –0.5	–0.6 to –0.9
Transit ridership WRT transit fares	Peak	–0.15 to –0.3	–0.4 to –0.6
Transit ridership WRT transit fares	Off-peak	–0.3 to –0.6	–0.8 to –1.0
Transit ridership WRT transit fares	Suburban Commuters	–0.3 to –0.6	–0.8 to –1.0
Transit ridership WRT transit service	Overall	0.50 to 0.7	0.7 to 1.1
Transit ridership WRT auto operating costs	Overall	0.05 to 0.15	0.2 to 0.4
Automobile travel WRT transit costs	Overall	0.03 to 0.1	0.15 to 0.3

Note: WRT = with respect to; This table summarizes estimates of transit elasticities. These values can be used to predict how various types of changes in prices and service are likely to affect transit ridership and travel behavior.

Source: Victoria Transport Policy Institute (VTPI), 2008 [79]

The change of elasticity against fuel price is calculated with a 20% increase in fuel costs (from RM 1.60 /liter in 2007 to RM 1.92 /liter in 2009). Meanwhile, there is a 2.62% increase in bus passengers (from 3,927 passengers per day in 2007 to 4,030 passenger per day in 2009). The cross elasticity of demand to the fuel price is +0.142. It means, a 1% increase in fuel price will lead to a 0.142% increase in transit demand.

On the other hand, the elasticity of demand to income is +0.196. The demand will increase about 0.196% as the income (per capita) increase about 1%. For this case, in the public transport captive demand, the increase in income does not affect the decrease in transit use due to capability of buying private car. However, people with free option (rich) have naturally capable to choose to drive their own car since the bus service (public transport) is not attractive.

To attract more passengers using bus service (ridership), the quality of bus service has to be improved. A strategic option to improve quality of service is performed such as by changing frequency for attracting increased demand or ridership. The change of frequency to become 3 buses per hour is preferable which is at headway of 20 minute, capacity of 44 seats and 15 buses per day available with load factor of 27%. Other possible way, the capacity is changed to 25 seats, headway of 20 minute, frequency of 3 buses per hour, 15 buses per day and load factor of 59%.

Frequency change is likely preferable recommendation than the change in capacity due to the opportunity of raising load factor in future time. The frequency change in this case intends to increase ridership by adding number of buses. Adding buses is to reduce the passenger waiting time rather than to relieve overcrowding as the loading passenger is low. Accordingly, at this load factor, the bus service become comfortable, convenient and it will attract more bus users in long-term period. In comparison with increase in frequency, Evans [78, 79] stated that the elasticity of transit use to service expansion is typically in the range of 0.6 to 1.0, meaning that each 1% of additional service (measured in vehicle-miles or vehicle-hours of service) increases ridership by 0.6-1.0%, although much lower and higher response rates are also found (from less than 0.3 to more than 1.0).

In the headway factor, alternative 2 is a preferred strategy with headway elasticity of -0.09319. The headway changes from 39.66 to 20 minute (49.57%) will cause the 2.62% increase in bus service demand. Negative sign of headway elasticity means the relative decrease in headway will cause the relative increase in demand. However, headway change is a direct inelastic factor to demand change. In other study, according to Evans [78, 79], the elasticity of transit use with respect to transit service frequency (called a headway elasticity) averages 0.5.

Travel time is the significant elastic factor due to its high elasticity. In this case, bus service demand changes sensitively with respect to relative change in travel time. This shows that approximately 1% increase in travel time causes 4,057% decrease in passenger per day. Consequently, it can be elaborated the effort on reducing travel time to attract more bus service users. It may be possible to improve the traffic management system and bus service quality control for reducing delay, waiting time and running travel time.

As mentioned in Table 6.29 above, the reliability factor such as punctuality index, waiting time, regularity and on-time performance indicate as the elastic factors to the sensitivity of bus service demand. All their absolute values of elasticity are more than one. Naturally, the demand of bus service increases when the level of service quality increases. Therefore, the reliability of bus service performance is necessary to be improved for achieving viable and reasonable standard. Those factors are among the reasonable measurements to attract more bus service passengers.

6.4 Measurement and Indicators of Improvement

This section highlights the measurements and indicators of bus service improvement. The measurements include increasing punctuality, reducing waiting time, increasing level of service and increasing on-time performance and regularity. The explanation is extended to the effect of level of service and regularity to bus service demand.

6.4.1 Improvement Measurements

Among the important problems regarding to the current bus service are including long waiting time, low passengers loading and low reliability. Therefore, the strategic operational planning to overcome the respective problems is directed such as:

a. to reduce waiting time by shortening the headway
b. to attract more passengers using bus service

c. to increase reliability (on-time performance, punctuality and regularity)

The magnitude of public transport demand can be indicated by the load factor level. In analysis of public transport demand, for approach, the load factor (LF) can be used to represent the level of bus service demand. Generally, demand of public transportation tends to increase as the level of service increases. The level of service of bus operation is determined by some variables of reliability such as on-time performance, punctuality, waiting time and regularity. Data used for analysis of level of demand are detailed in Table 6.31.

The increase of load factor is affected by a number of factors as follows:

1. increasing punctuality (percentage)
2. decreasing waiting time
3. increasing level of service (LOS)
4. increasing regularity or on-time performance

Table 6.31 Load factor, trip productivity and selected variables

				Pass/bus/day			Punctualityp = 1-P_I (%)		Waiting time	
No	Month	Date	LF (%)	off peak	peak	total	due to H-30'	due to H-60'	due to H-30'	due to H-60'
1	Jan	25-Jan-07	48	147	177	324	64.3	91.1	20.4	32.7
2		27-Jan-07	75	297	210	507	41.2	85.3	23.8	34.4
3	Feb	14-Feb-07	39	75	237	312	84.2	96.0	17.4	31.2
4		11-Feb-07	79	159	222	381	93.4	98.3	16.0	30.5
5	Mar	14-Mar-07	76	165	396	561	49.3	87.3	22.6	33.8
6		18-Mar-07	84	222	204	426	97.4	99.3	15.4	30.2
7	Apr	11-Apr-07	44	81	378	459	92.1	98.0	16.2	30.6
8		14-Apr-07	79	228	222	450	88.2	97.1	16.8	30.9
9	May	9-May-07	38	114	198	312	78.0	94.5	18.3	31.7
10		12-May-07	32	66	165	231	94.9	98.7	15.8	30.4
11	Jun	6-Jun-07	42	60	162	222	93.8	98.4	15.9	30.5
12		2-Jun-07	77	312	222	534	58.6	89.6	21.2	33.1
13	Jul	25-Jul-07	33	63	249	312	96.8	99.2	15.5	30.2
14		29-Jul-07	54	78	243	321	91.7	97.9	16.2	30.6
15	Aug	22-Aug-07	22	33	105	138	76.9	94.2	18.5	31.7
16		18-Aug-07	38	126	141	267	71.3	92.8	19.3	32.2
17	Sep	19-Sep-07	59	195	99	294	48.6	87.2	22.7	33.9
18		22-Sep-07	61	153	198	351	13.8	78.5	27.9	36.5
19	Oct	31-Oct-07	46	120	111	231	90.5	97.6	16.4	30.7
20		27-Oct-07	74	135	177	312	93.1	98.3	16.0	30.5
21	Nov	6-Nov-07	82	177	294	471	81.2	95.3	17.8	31.4
22		3-Nov-07	61	180	222	402	67.1	91.8	19.9	32.5
23	Dec	5-Dec-07	83	123	375	498	59.3	89.8	21.1	33.1
24		8-Dec-07	85	165	297	462	88.2	97.1	16.8	30.9
	Average		59	145	221	366	76	94	19	32
	Min		22	33	99	138	14	78	15	30
	Max		85	312	396	561	97	99	28	36
	St.dev		20.1	71.7	80.9	111.2	21.5	5.4	3.2	1.6
	Variance		402.1	5146.6	6540.0	12367.5	462.0	28.9	10.4	2.6
	Coef. of Variation		34.1	49.6	36.6	30.4	28.4	5.7	17.3	5.1

Table 6.31 Load factor, trip productivity and selected variables (continued)

			LOS value		LOS level		Regularity		
No	Month	Date	due to H-30'	due to H-60'	due to H-30'	due to H-60'	% pass within 5 min	% pass within 10 min	% pass within 15 min
1	Jan	25-Jan-07	0.60	0.30	E	B	0.0	8.3	66.7
2		27-Jan-07	0.77	0.38	F	C	0.0	0.0	27.3
3	Feb	14-Feb-07	0.40	0.20	F	A	16.7	50.0	66.7
4		11-Feb-07	0.26	0.13	B	A	25.0	66.7	100.0
5	Mar	14-Mar-07	0.71	0.36	E	C	0.0	25.0	25.0
6		18-Mar-07	0.16	0.08	A	A	66.7	100.0	100.0
7	Apr	11-Apr-07	0.28	0.14	B	A	75.0	75.0	83.3
8		14-Apr-07	0.34	0.17	C	A	41.7	58.3	75.0
9	May	9-May-07	0.47	0.23	D	B	8.3	41.7	75.0
10		12-May-07	0.23	0.11	B	A	41.7	75.0	100.0
11	Jun	6-Jun-07	0.25	0.13	B	A	41.7	75.0	83.3
12		2-Jun-07	0.64	0.32	E	C	0.0	27.3	27.3
13	Jul	25-Jul-07	0.18	0.09	A	A	66.7	83.3	91.7
14		29-Jul-07	0.29	0.14	B	A	41.7	50.0	75.0
15	Aug	22-Aug-07	0.48	0.24	D	B	66.7	83.3	91.7
16		18-Aug-07	0.54	0.27	E	B	41.7	50.0	75.0
17	Sep	19-Sep-07	0.72	0.36	E	C	8.3	33.3	66.7
18		22-Sep-07	0.93	0.46	F	D	0.0	0.0	0.0
19	Oct	31-Oct-07	0.31	0.15	F	A	45.5	63.6	72.7
20		27-Oct-07	0.26	0.13	B	A	50.0	66.7	83.3
21	Nov	6-Nov-07	0.43	0.22	D	F	27.3	45.5	63.6
22		3-Nov-07	0.57	0.29	E	B	0.0	50.0	66.7
23	Dec	5-Dec-07	0.64	0.32	E	C	0.0	8.3	58.3
24		8-Dec-07	0.34	0.17	C	A	25.0	66.7	75.0
	Average		0	0	D	B	29	50	69
	Min		0	0			0	0	0
	Max		1	0			75	100	100
	St.dev		0.2	0.1			25.4	27.7	25.6
	Variance		0.0	0.0			644.0	768.1	654.9
	Coef. of Variation		46.6	46.6			88.3	55.3	37.2

The visualization of some measurements above is sequentially shown below. Figure 6.14 visualizes load factor (%) and trip productivity (passengers/bus/day) in 2007. Punctuality index for both 30 and 60 minute headway in 2007 is shown in Figure 6.15.

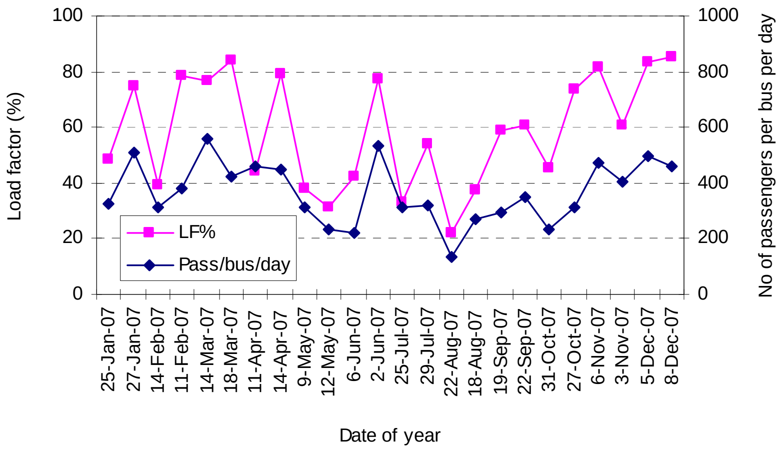


Figure 6.14 Load factor (%) and trip productivity (passengers/bus/day) in 2007

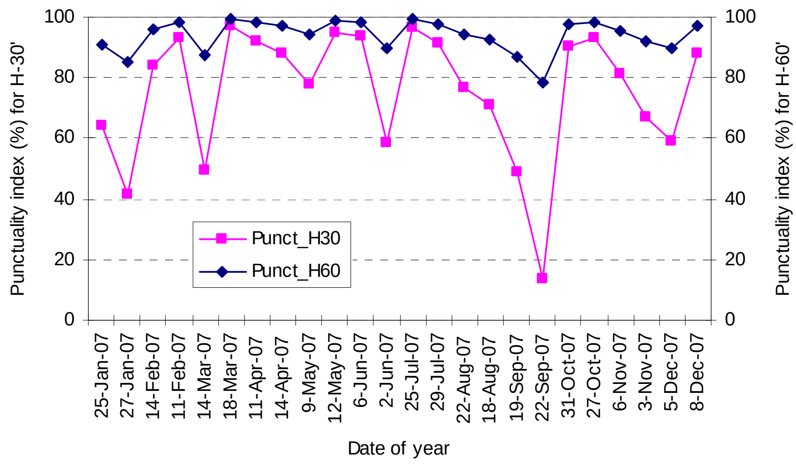


Figure 6.15 Punctuality index for both 30 and 60 minute headway in 2007

Waiting time is calculated based on two categories of 30 and 60 minute service headway. Figure 6.16 shows the waiting time for both 30 and 60 minute headway in 2007. Level of service for both 30 and 60 minute headway in 2007 is shown in Figure 6.17. LOS value is functionally derived from headway adherence. Its value is separately calculated in according to 30 and 60 minute headway. The low value of LOS is the better quality of service, thus, showing the higher quality bus service. Figure 6.18 shows the various regularities in term of its arrival within ±5 minute and within ±10 minute in 2007. In term of its arrival time the regularity within ±5 minute is lower than those within ±10 minute.

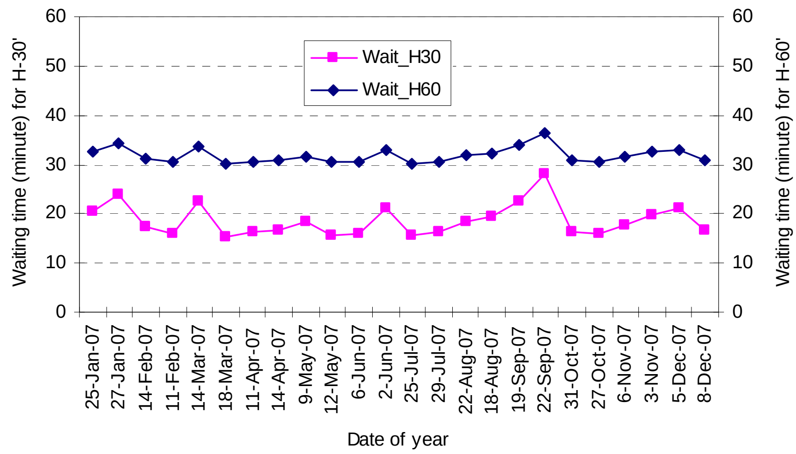


Figure 6.16 Waiting time for both 30 and 60 minute headway in 2007

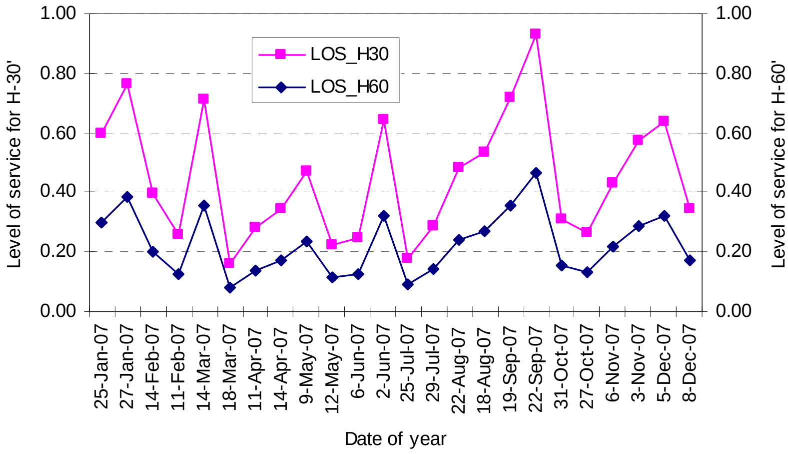


Figure 6.17 Level of service for both 30 and 60 minute headway in 2007

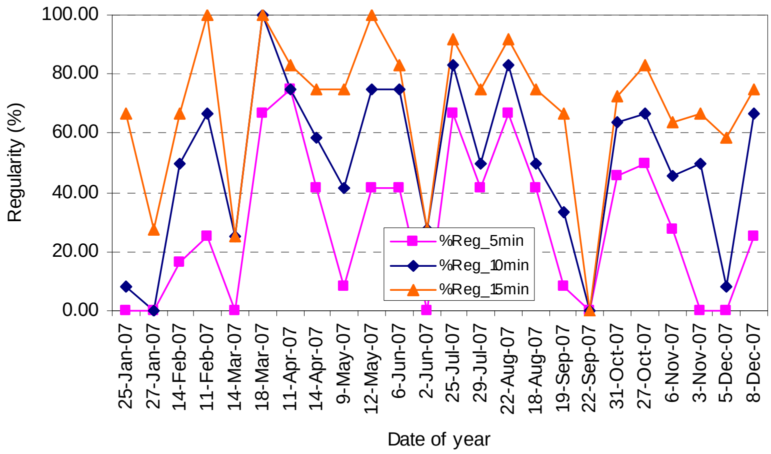


Figure 6.18 Regularity in term of its arrival time in 2007

6.4.2 Effect of LOS and Regularity to Load Factor and Number of Passengers

a. <u>Simple regression</u>

Before we assess the effect of punctuality and regularity to the load factor, the relevance of a number of variables are necessary to be evaluated. The relevance is performed by evaluating the sign of coefficient of simple regression. Regression is made between a dependent variable and some independent variables. The dependent variable is load factor or number of passengers. A number of independent variables are punctuality index, waiting time, LOS value and regularity. In other words, the trip productivity of bus service is assumed as dependent variable, while the perceived characteristics above are assumed as independent variables.

From Table 6.32 we can see that punctuality and regularity variables give negative sign (-) to both load factor and number of passengers. In the perspective of technical operation, the higher punctuality index (P_I in %) and regularity (%), the lower load factor (passengers loading) or number of passengers is. Meanwhile, in technical operation, the increase of waiting time and LOS value causes the increase of load factor or number of passengers. Both waiting time and LOS value have positive sign (+) of coefficient of regression.

Otherwise, in the perspective of user's perception on how interesting quality of bus service, the phenomena might oppositely happen. For example, if the punctuality index and regularity increase than load factor or number of passengers will increase.

Table 6.32 Relevance of LF and number of passengers with reliability variables

1. Formula of regression

Dependent variable	Time of day	Independent variable		
		punctuality	waiting time	LOS value
Load factor	off peak (H60)	y = -0.7292x + 127.29 R2 = 0.0409	y = 2.4307x - 18.548 R2 = 0.0409	y = 36.853x + 50.539 R2 = 0.0369
	peak (H30)	y = -0.1823x + 72.604 R2 = 0.0409	y = 1.2154x + 36.143 R2 = 0.0409	y = 18.427x + 50.539 R2 = 0.0369
Pass/bus/day	off peak (H60)	y = -2.2054x + 572.83 R2 = 0.0117	y = 7.3514x + 131.75 R2 = 0.0117	y = 116.53x + 339.55 R2 = 0.0115
	peak (H30)	y = -0.5514x + 407.42 R2 = 0.0117	y = 3.6757x + 297.15 R2 = 0.0117	y = 58.263x + 339.55 R2 = 0.0115

Dependent variable	Time of day	Independent variable		
		regularity_5min	regularity_10min	regularity_15min
Load factor		y = -0.3344x + 68.43 R2 = 0.1751	y = -0.2347x + 70.587 R2 = 0.0885	y = -0.3344x + 68.43 R2 = 0.1751
Pass/bus/day		y = -1.4883x + 408.5 R2 = 0.1087	y = -1.11x + 421.39 R2 = 0.0621	y = -1.9379x + 498.92 R2 = 0.1259

2. Coefficients of regression

Dependent variable	Time of day	Independent variable		
		punctuality	waiting time	LOS value
Load factor	off peak (H60)	(-)	(+)	(+)
	peak (H30)	(-)	(+)	(+)
Pass/bus/day	off peak (H60)	(-)	(+)	(+)
	peak (H30)	(-)	(+)	(+)

Dependent variable	Time of day	Independent variable		
		regularity_5min	regularity_10min	regularity_15min
Load factor	-	(-)	(-)	(-)
Pass/bus/day	-	(-)	(-)	(-)

b. Multiple linear regression

Analysis of multiple linear regressions is used to predict the relationship between load factor and a number of selected independent variables. The significance of regression is tested by using ANOVA test. Assumption is taken that significance level is 5% (confidence limit = 95%), k=2, n-k-1=24-2-1= 21, degree of freedom df1 = 2 and df2 = 21. Therefore, the value of critical F-statistic is 3.4668. The regression is significance if F-statistical higher than critical F-statistical.

The significance of regression coefficient is tested by assumption such as 5% degree of significance and degree of freedom = 24-2=22. Thus, the t-critical is 2.074. The coefficient of regression is significance if t-statistic higher than t-critical. It means that independent variable significantly explains the variability of dependent variable.

By performing multiple regression analysis the empirical relationship can be obtained. For predicting the demand on public transport, the reliability (punctuality and regularity) is considered as the independent variables. And, the load factor (%) and number of passengers are assumed as the demand for public transport. The results are tabulated in Table 6.33 to Table 6.39. Meanwhile, Figure 6.19 and Figure 6.20 show the predicted and actual value of both load factor and number of passengers per bus per day. The equations are as follows:

i. *LF%* = 94.128*(*LOS_H30*) + 0.4676*(*%Reg_5min*)

ii. *LF%* = 188.26* (*LOS_H60*) + 0.4676*(*%Reg_5min*)

iii. *Pass/bus/day* = 599.49*(*LOS_H30*) + 2.7882*(*%Reg_5min*)

iv. *Pass/bus/day* = 1199*(*LOS_H60*) + 2.7882*(*%Reg_5min*)

The statistical closeness value is used to evaluate the alternative of analysis such as MARE (mean absolute relative error) and MAPPE (mean absolute percentage prediction error). Value of MARE and MAPPE are shown in Table 6.35. But, the appropriate results are mainly considered by using the correct sign and significance coefficient of regression (t-test) and also significance of regression (ANOVA test or F-test), as shown in Table 6.38 and Table 6.39.

Table 6.33 Testing of load factor (LF) against reliability of bus service

Alt.	Variable	Parameters					Results
1.	LF% is function of	Adjusted R Square	0.813				
	Punct_H30	F	70.243				model is significant
	%Reg_5min	0	Coefficients	Standard Error	t Stat	P-value	
		Intercept	0	#N/A	#N/A	#N/A	
		Punct_H30	1.0293	0.1204	8.55078	2E-08	coefficient is significant
		%Reg_5min	-0.771	0.2487	-3.10085	0.0052	coefficient is not significant
2.	LF% is function of	Adjusted R Square	0.8639				
	Punct_H60	F	115.84				model is significant
	%Reg_5min	0	Coefficients	Standard Error	t Stat	P-value	
		Intercept	0	#N/A	#N/A	#N/A	
		Punct_H60	0.747	0.0664	11.2474	1E-10	coefficient is significant
		%Reg_5min	-0.395	0.1645	-2.40235	0.0252	coefficient is not significant
3.	LF% is function of	Adjusted R Square	0.844				
	Wait_H30	F	93.071				model is significant
	%Reg_5min	0	Coefficients	Standard Error	t Stat	P-value	
		Intercept	0	#N/A	#N/A	#N/A	
		Wait_H30	3.0416	0.3044	9.99212	1E-09	coefficient is significant
		%Reg_5min	0.042	0.1517	0.27695	0.7844	coefficient is not significant
4.	LF% is function of	Adjusted R Square	0.8595				
	Wait_H60	F	109.95				model is significant
	%Reg_5min	0	Coefficients	Standard Error	t Stat	P-value	
		Intercept	0	#N/A	#N/A	#N/A	
		Wait_H60	2.0073	0.1835	10.9363	2E-10	coefficient is significant
		%Reg_5min	-0.181	0.154	-1.17596	0.2522	coefficient is not significant
5.	LF% is function of	Adjusted R Square	0.797				
	LOS_H30	F	62.004				model is significant
	%Reg_5min	0	Coefficients	Standard Error	t Stat	P-value	
		Intercept	0	#N/A	#N/A	#N/A	
		LOS_H30	94.128	11.815	7.96682	6E-08	coefficient is significant
		%Reg_5min	0.4676	0.1537	3.042	0.006	coefficient is significant
6.	LF% is function of	Adjusted R Square	0.797				
	LOS_H60	F	62.004				model is significant
	%Reg_5min	0	Coefficients	Standard Error	t Stat	P-value	
		Intercept	0	#N/A	#N/A	#N/A	
		LOS_H60	188.26	23.63	7.96682	6E-08	coefficient is significant
		%Reg_5min	0.4676	0.1537	3.042	0.006	coefficient is significant

Table 6.34 Testing of number of passengers against reliability of bus service

Alte.	Variable	Parameters					Results
1.	Pass/bus/day is	Adjusted R Square	0.8175				
	function of	F	72.888				model is significant
	Punct_H30	0	Coefficients	Standard Error	t Stat	P-value	
	%Reg_5min	Intercept	0	#N/A	#N/A	#N/A	
		Punct_H30	6.3311	0.729	8.6851	1E-08	coefficient is significant
		%Reg_5min	-4.704	1.5059	-3.124	0.0049	coefficient is not significant
2.	Pass/bus/day is	Adjusted R Square	0.8822				
	function of	F	148.06				model is significant
	Punct_H60	0	Coefficients	Standard Error	t Stat	P-value	
	%Reg_5min	Intercept	0	#N/A	#N/A	#N/A	
		Punct_H60	4.6562	0.365	12.757	1E-11	coefficient is significant
		%Reg_5min	-2.51	0.9038	-2.777	0.011	coefficient is not significant
3.	Pass/bus/day is	Adjusted R Square	0.8713				
	function of	F	127.13				model is significant
	Wait_H30	0	Coefficients	Standard Error	t Stat	P-value	
	%Reg_5min	Intercept	0	#N/A	#N/A	#N/A	
		Wait_H30	19.13	1.6259	11.766	6E-11	coefficient is significant
		%Reg_5min	0.1577	0.8103	0.1946	0.8475	coefficient is not significant
4.	Pass/bus/day is	Adjusted R Square	0.8827				
	function of	F	148.98				model is significant
	Wait_H60	0	Coefficients	Standard Error	t Stat	P-value	
	%Reg_5min	Intercept	0	#N/A	#N/A	#N/A	
		Wait_H60	12.569	0.9821	12.799	1E-11	coefficient is significant
		%Reg_5min	-1.212	0.8241	-1.47	0.1556	coefficient is not significant
5.	Pass/bus/day is	Adjusted R Square	0.8342				
	function of	F	84.581				model is significant
	LOS_H30	0	Coefficients	Standard Error	t Stat	P-value	
	%Reg_5min	Intercept	0	#N/A	#N/A	#N/A	
		LOS_H30	599.49	63.541	9.4347	3E-09	coefficient is significant
		%Reg_5min	2.7882	0.8267	3.3726	0.0027	coefficient is significant
6.	Pass/bus/day is	Adjusted R Square	0.8342				
	function of	F	84.581				model is significant
	LOS_H60	0	Coefficients	Standard Error	t Stat	P-value	
	%Reg_5min	Intercept	0	#N/A	#N/A	#N/A	
		LOS_H60	1199	127.08	9.4347	3E-09	coefficient is significant
		%Reg_5min	2.7882	0.8267	3.3726	0.0027	coefficient is significant

Table 6.35 MARE and MAPPE values of load factor and number of passenger

No Alte.	Variable	Load factor MARE	Load factor MAPPE	Variable	Pass/bus/day MARE	Pass/bus/day MAPPE
1.	LF% is function of Punct_H30 %Reg_5min	19.659	44.968	Pass/bus/day is function of Punct_H30 %Reg_5min	114.2	43.318
2.	LF% is function of Punct_H60 %Reg_5min	15.887	27.54	Pass/bus/day is function of Punct_H60 %Reg_5min	88.576	25.152
3.	LF% is function of Wait_H30 %Reg_5min	17.306	30.972	Pass/bus/day is function of Wait_H30 %Reg_5min	91.438	25.057
4.	LF% is function of Wait_H60 %Reg_5min	16.384	28.896	Pass/bus/day is function of Wait_H60 %Reg_5min	88.712	24.759
5.	LF% is function of LOS_H30 %Reg_5min	19.421	36.363	Pass/bus/day is function of LOS_H30 %Reg_5min	103.62	28.935
6.	LF% is function of LOS_H60 %Reg_5min	19.421	36.363	Pass/bus/day is function of LOS_H60 %Reg_5min	103.62	28.935

Table 6.36 Data of the load factor (LF), LOS and regularity

LF%	Alternative 5 LOS_H30	Alternative 5 %Reg_5min	Alternative 6 LOS_H60	Alternative 6 %Reg_5min
48.173	0.5976	0	0.2988	0
75.077	0.7667	0	0.3833	0
39.334	0.3976	16.667	0.1988	16.667
78.822	0.2571	25	0.1286	25
76.443	0.7119	0	0.356	0
84.29	0.1619	66.667	0.081	66.667
44.295	0.281	75	0.1405	75
79.395	0.3429	41.667	0.1714	41.667
37.732	0.469	8.3333	0.2345	8.3333
31.544	0.2262	41.667	0.1131	41.667
42.485	0.25	41.667	0.125	41.667
77.117	0.6436	0	0.3218	0
33.419	0.1786	66.667	0.0893	66.667
54.081	0.2881	41.667	0.144	41.667
21.944	0.481	66.667	0.2405	66.667
37.56	0.5357	41.667	0.2679	41.667
58.722	0.7167	8.3333	0.3583	8.3333
60.996	0.9282	0	0.4641	0
45.682	0.3077	45.455	0.1538	45.455
73.797	0.2619	50	0.131	50
81.534	0.4333	27.273	0.2167	27.273
60.64	0.5738	0	0.2869	0
83.404	0.6381	0	0.319	0
85.308	0.3429	25	0.1714	25

Table 6.37 Data of the number of passenger, LOS and regularity

Pass/bus/day	Alternative 5		Alternative 6	
	LOS_H30	%Reg_5min	LOS_H60	%Reg_5min
324	0.5976	0	0.2988	0
507	0.7667	0	0.3833	0
312	0.3976	16.667	0.1988	16.667
381	0.2571	25	0.1286	25
561	0.7119	0	0.356	0
426	0.1619	66.667	0.081	66.667
459	0.281	75	0.1405	75
450	0.3429	41.667	0.1714	41.667
312	0.469	8.3333	0.2345	8.3333
231	0.2262	41.667	0.1131	41.667
222	0.25	41.667	0.125	41.667
534	0.6436	0	0.3218	0
312	0.1786	66.667	0.0893	66.667
321	0.2881	41.667	0.144	41.667
138	0.481	66.667	0.2405	66.667
267	0.5357	41.667	0.2679	41.667
294	0.7167	8.3333	0.3583	8.3333
351	0.9282	0	0.4641	0
231	0.3077	45.455	0.1538	45.455
312	0.2619	50	0.131	50
471	0.4333	27.273	0.2167	27.273
402	0.5738	0	0.2869	0
498	0.6381	0	0.319	0
462	0.3429	25	0.1714	25

Table 6.38 Regression output for LF to LOS and regularity

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.9216
R Square	0.8493
Adjusted R Square	0.797
Standard Error	25.142
Observations	24

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	78389	39194.7	62.004	2E-09
Residual	22	13907	632.13		
Total	24	92296			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
LOS_H30	94.128	11.815	7.96682	6E-08	69.625	118.63	69.625	118.63
%Reg_5min	0.4676	0.1537	3.042	0.006	0.1488	0.7864	0.1488	0.7864

RESIDUAL OUTPUT

PROBABILITY OUTPUT

Observation	*Predicted LF%*	*Residuals*	*Standard Residuals*	*Percentile*	*LF%*	MARE	MAPPE
1	56.253	-8.08	-0.33565	2.0833	21.944	8.0798	14.363
2	72.165	2.9127	0.121	6.25	31.544	2.9127	4.0362
3	45.221	-5.887	-0.24457	10.417	33.419	5.8872	13.019
4	35.895	42.927	1.7833	14.583	37.56	42.927	119.59
5	67.01	9.4329	0.39186	18.75	37.732	9.4329	14.077
6	46.415	37.875	1.5734	22.917	39.334	37.875	81.6
7	61.518	-17.22	-0.71548	27.083	42.485	17.223	27.996
8	51.757	27.638	1.14816	31.25	44.295	27.638	53.4
9	48.047	-10.31	-0.42851	35.417	45.682	10.315	21.468
10	40.775	-9.232	-0.3835	39.583	48.173	9.2316	22.64
11	43.017	-0.531	-0.02207	43.75	54.081	0.5313	1.235
12	60.58	16.537	0.68698	47.917	58.722	16.537	27.298
13	47.984	-14.56	-0.60505	52.083	60.64	14.565	30.353
14	46.602	7.4781	0.31066	56.25	60.996	7.4781	16.047
15	76.446	-54.5	-2.26418	60.417	73.797	54.503	71.296
16	69.91	-32.35	-1.34392	64.583	75.077	32.351	46.274
17	71.355	-12.63	-0.52483	68.75	76.443	12.634	17.705
18	87.37	-26.37	-1.09564	72.917	77.117	26.374	30.187
19	50.218	-4.537	-0.18846	77.083	78.822	4.5366	9.0337
20	48.034	25.763	1.07024	81.25	79.395	25.763	53.634
21	53.542	27.992	1.16284	85.417	81.534	27.992	52.28
22	54.012	6.629	0.27538	89.583	83.404	6.629	12.273
23	60.063	23.342	0.96967	93.75	84.29	23.342	38.862
24	43.963	41.345	1.71755	97.917	85.308	41.345	94.043
						19.421	36.363

Table 6.39 Regression output for number of passengers to LOS and regularity

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.9407
R Square	0.8849
Adjusted R Square	0.8342
Standard Error	135.21
Observations	24

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	3E+06	2E+06	84.581	9E-11
Residual	22	402223	18283		
Total	24	3E+06			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
LOS_H30	599.49	63.541	9.4347	3E-09	467.71	731.26	467.71	731.26
%Reg_5min	2.7882	0.8267	3.3726	0.0027	1.0737	4.5027	1.0737	4.5027

RESIDUAL OUTPUT

PROBABILITY OUTPUT

Observation	*Predicted Pass/bus/day*	*Residuals*	*Standard Residuals*	*Percentile*	*Pass/bus/day*	MARE	MAPPE
1	358.27	-34.27	-0.265	2.0833	138	34.265	9.5642
2	459.61	47.393	0.3661	6.25	222	47.393	10.312
3	284.84	27.163	0.2098	10.417	231	27.163	9.5361
4	223.86	157.14	1.2138	14.583	231	157.14	70.197
5	426.78	134.22	1.0368	18.75	267	134.22	31.45
6	282.94	143.06	1.1051	22.917	294	143.06	50.562
7	377.54	81.458	0.6292	27.083	312	81.458	21.576
8	321.71	128.29	0.991	31.25	312	128.29	39.876
9	304.42	7.5769	0.0585	35.417	312	7.5769	2.4889
10	251.77	-20.77	-0.16	39.583	312	20.773	8.2507
11	266.05	-44.05	-0.34	43.75	321	44.047	16.556
12	385.82	148.18	1.1446	47.917	324	148.18	38.405
13	292.93	19.069	0.1473	52.083	351	19.069	6.5097
14	288.88	32.116	0.2481	56.25	381	32.116	11.117
15	474.2	-336.2	-2.597	60.417	402	336.2	70.899
16	437.33	-170.3	-1.316	64.583	426	170.33	38.948
17	452.87	-158.9	-1.227	68.75	450	158.87	35.08
18	556.45	-205.4	-1.587	72.917	459	205.45	36.921
19	311.19	-80.19	-0.619	77.083	462	80.194	25.77
20	296.42	15.582	0.1204	81.25	471	15.582	5.2567
21	335.82	135.18	1.0442	85.417	498	135.18	40.254
22	343.99	58.008	0.4481	89.583	507	58.008	16.863
23	382.53	115.47	0.892	93.75	534	115.47	30.186
24	275.24	186.76	1.4426	97.917	561	186.76	67.851
						103.62	28.935

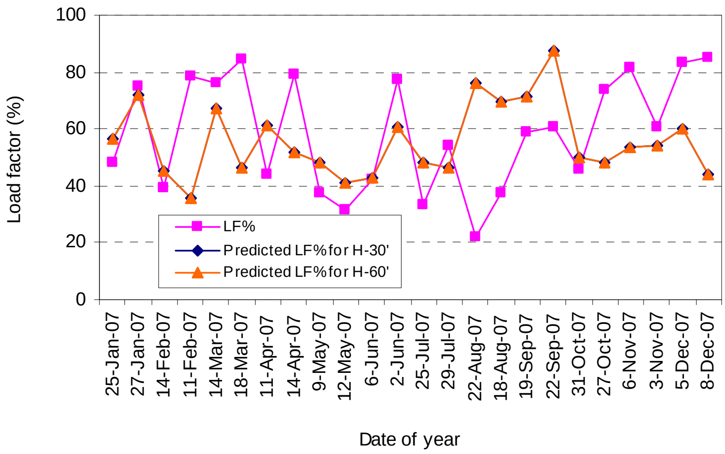


Figure 6.19 Predicted and actual load factor for both 30 and 60 minute headway

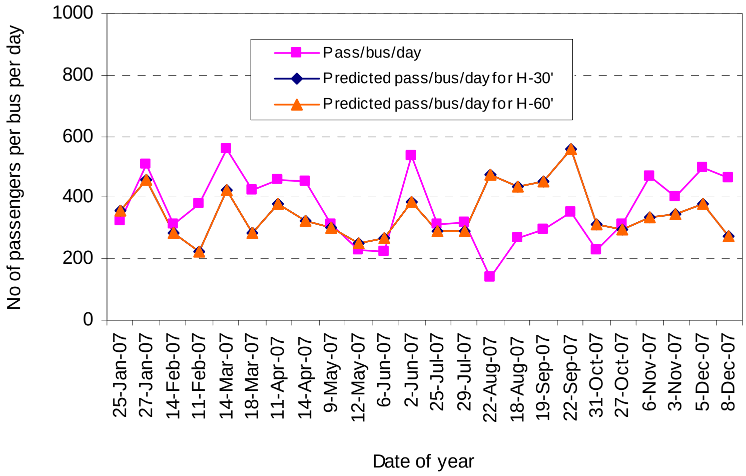


Figure 6.20 Predicted and actual number of passengers per bus per day

6.5 Distribution of Bus Service Demand

The demand of bus service in passengers per day by zone is shown in Table 6.5. Total of 2,560 boarding passengers per day is distributed in three zones, there are Kinta (558 boarding passengers), Perak Tengah (635 pasenggers) and Manjung (1,367 passengers). Meanwhile, alighting passengers per day are spread into Kinta (611), Perak Tengah (531 passengers) and Manjung (1,418 passengers). Detail distribution of passengers by zones is shown in Figure 6.21 to Figure 6.23. Other data explaining and completing the distribution of passengers per day are shown in Table 6.40 to Table 6.44.

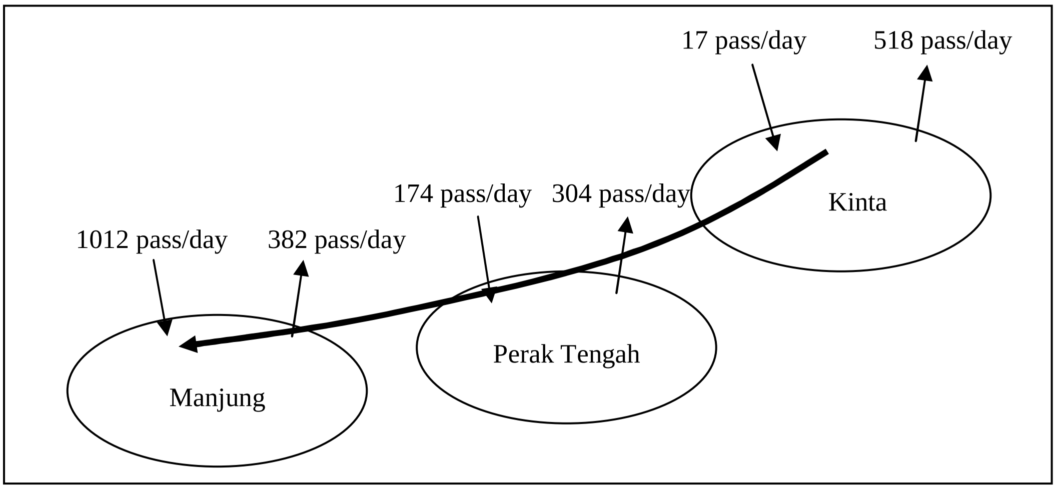


Figure 6.21 Get on and get off passengers from Ipoh to Lumut direction

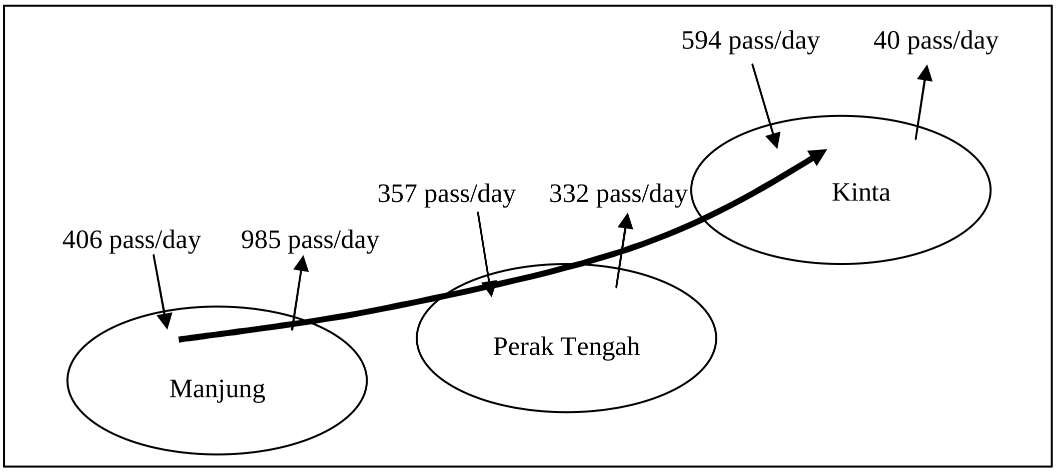


Figure 6.22 Get on and get off passengers from Lumut to Ipoh direction

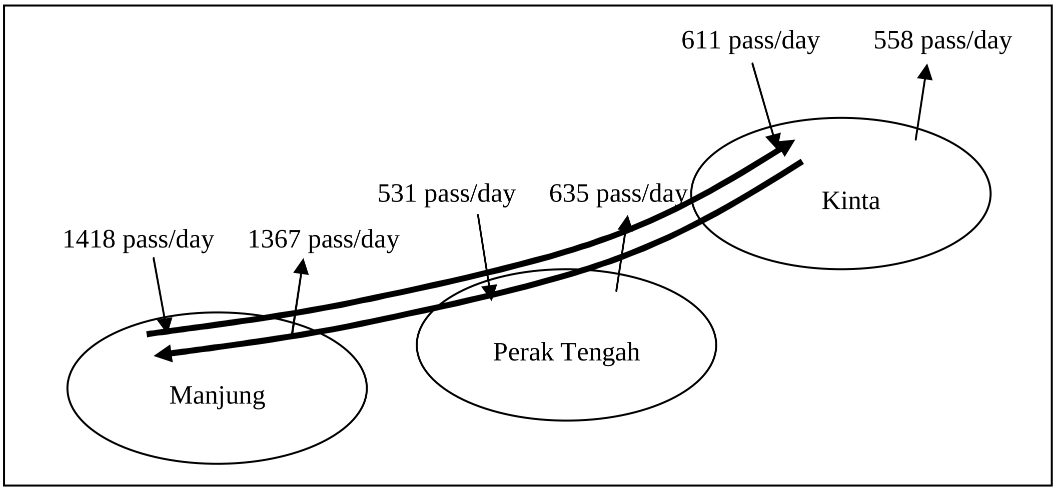


Figure 6.23 Get on and get off passengers for two ways trip

Table 6.40 Trip productions and attractions each zone in passengers per day

Zone	Demand (passengers per day)					
	Average-scenario		Minimum-scenario		Maximum-scenario	
	Productions	Attractions	Productions	Attractions	Productions	Attractions
Kinta	558	611	210	231	777	861
Perak Tengah	635	531	210	357	777	882
Manjung	1,367	1,418	546	378	2,373	2,184
Total	2,560	2,560	966	966	3,927	3,927

Table 6.41 Matrix of distance between two zones (districts)

	Distance (km)		
	Kinta	Perak Tengah	Manjung
Kinta	30.1	32.9	75.3
Perak Tengah	32.9	19.6	42.4
Manjung	75.3	42.4	33.1

Table 6.42 Matrix of operating speed between two zones (districts)

	Operating speed (km/h)		
	Kinta	Perak Tengah	Manjung
Kinta	49.4	46.7	42.8
Perak Tengah	43.0	42.5	41.0
Manjung	39.4	37.7	37.2

Table 6.43 Matrix of travel time (hour) between two zones (districts)

	Travel time (hour)		
	Kinta	Perak Tengah	Manjung
Kinta	0.61	0.70	1.76
Perak Tengah	0.77	0.46	1.03
Manjung	1.91	1.12	0.89

Table 6.44 Matrix of travel time (minute) between two zones (districts)

	Travel time (minute)		
	Kinta	Perak Tengah	Manjung
Kinta	36.4	42.3	105.6
Perak Tengah	45.9	27.4	62.0
Manjung	114.7	67.5	53.4

6.5.1 Calibrated Gravity Model

The gravity model was applied for bus service passenger trips. The internal-internal trip distribution within Ipoh-Lumut corridor was considered. Altogether 3 zones based on the administrative boundary are defined as internal zones in this corridor such as Kinta (zone 1), Perak Tengah (zone 2) and Manjung (zone 3). To produce the friction factor in gravity model, the trip impedance assumed by using travel time data from the field data survey. In fact, the increasing travel time affects friction factor decreases which upon the zonal condition and interaction. Table 6.43 shows the travel time (in hour) as the trip impedance each pair of zones. The initial friction factor is calculated by using the negative exponential function (See Table 6.45).

Trips distribution of passenger per day each pair of zones resulted from the model are indicated in Table 6.46. This table contains all the scenarios of trip distribution obtained from the gravity model estimation. These directional trips distribution of bus service passenger are also visualized in Figure 6.24 and Figure 6.25.

Table 6.45 Friction factor for the iteration in gravity model

	Destination		
Origin	Kinta	Perak Tengah	Manjung
1. Kinta	2.71	2.01	0.32
2. Perak Tengah	1.71	4.80	0.94
3. Manjung	0.27	0.79	1.26

Table 6.46 Trip between zones for maximum-scenario (passenger per day)

	Destination			
Origin	Zone 1	Zone 2	Zone 3	Total production (P_i)
	Average-scenario			
Zone 1	336	129	93	558
Zone 2	171	247	217	635
Zone 3	104	155	1,108	1,367
Total attraction (A_j)	611	531	1,418	2,560
	Minimum-scenario			
Zone 1	118	76	16	210
Zone 2	51	126	33	210
Zone 3	62	155	329	546
Total attraction (A_j)	231	357	378	966
	Maximum-scenario			
Zone 1	461	204	113	777
Zone 2	205	342	230	777
Zone 3	196	336	1,841	2,373
Total attraction (A_j)	861	882	2,184	3,927

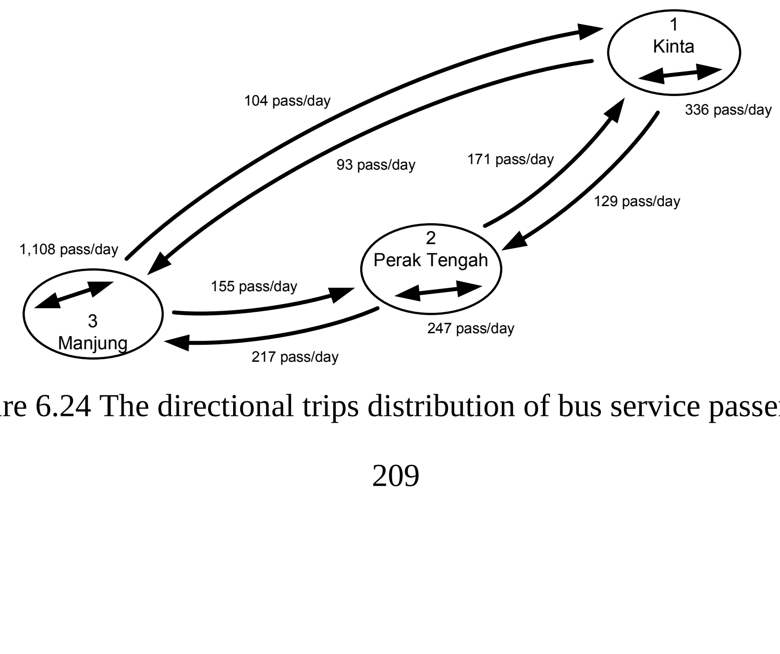


Figure 6.24 The directional trips distribution of bus service passengers

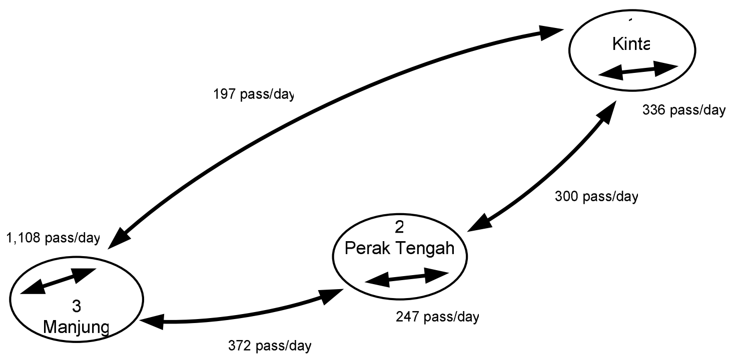


Figure 6.25 The trips distribution of bus service passengers (total trip of two ways)

After 6th iteration in calibration process the smoothed friction factor become (See Figure 6.26). The equation of friction factor is obtained as below.

$$F_{ij} = 0.97/(t_{ij})^{1.765} \quad (6.6)$$

with $R^2 = 0.9252$

Calibrated friction factors and zonal adjustment factor are tabulated in Table 6.47. In matrix form (zone-by-zone), both calibrated F_{ij} and K_{ij} obtained after 6th iteration are indicated in Table 6.48 and Table 6.49.

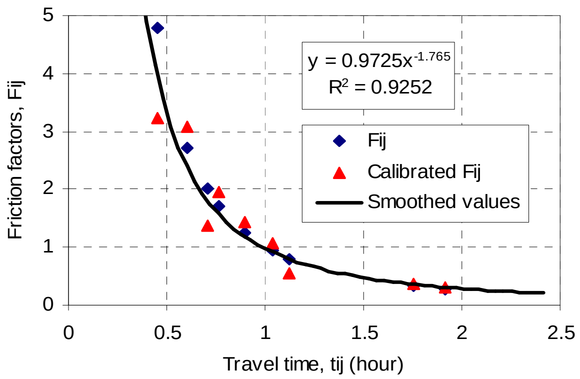


Figure 6.26 Actual, calibrated and smoothed values of friction factor

Table 6.47 The trip distribution and its calibrated F_{ij} and K_{ij}

Route	Travel time (hour)	F_{ij}	K_{ij}	Trips	Calibrated F_{ij}	Calibrated K_{ij}
1-1	0.61	2.71	1	336	3.09	0.75
1-2	0.70	2.01	1	129	1.36	1.89
1-3	1.76	0.32	1	93	0.37	0.84
2-1	0.77	1.71	1	171	1.94	0.75
2-2	0.46	4.80	1	247	3.24	2.06
2-3	1.03	0.94	1	217	1.06	0.73
3-1	1.91	0.27	1	104	0.31	0.92
3-2	1.12	0.79	1	155	0.53	1.78
3-3	0.89	1.26	1	1,108	1.43	0.76
				2,560		

Table 6.48 Friction factor matrix (calibrated F_{ij})

	Destination		
Origin	Zone 1	Zone 2	Zone 3
Zone 1	3.09	1.36	0.37
Zone 2	1.94	3.24	1.06
Zone 3	0.31	0.53	1.43

Table 6.49 Zonal adjustment factor matrix (calibrated K_{ij})

	Destination		
Origin	Zone 1	Zone 2	Zone 3
Zone 1	0.75	1.89	0.84
Zone 2	0.75	2.06	0.73
Zone 3	0.92	1.78	0.76

6.5.2 Travel Time Distribution and Average Travel Time

The travel time frequency distribution is calculated by accumulating the trip each pair of zones according to the travel impedance between zones, therefore the percentage of total trip in each travel impedance increment can be obtained. The average travel time is the weighted mean value of travel impedance, with the trip as the weight.

After 6 iterations, the travel time frequency distribution diagrams is illustrated in Figure 6.27 using K-factor adjustments equals to 1. The graph shown in Figure 6.27 is a plot of the percent of total trips that occur for each separation in hours. Figure 6.27 shows a typical comparison between the travel time frequency distribution for bus passenger trips, as estimated by the gravity model and the observed travel time frequency distribution. Horizontal axis shows zone separations in hours on the X-axis and vertical axis expresses percent of total passenger trips on the Y-axis. Percentage means the number of trips at each hour of separation is divided by the total number of trips and the result is multiplied by 100. The results are plotted with the hours of zone separations on the X-axis and the percent of trips on the Y-axis.

After 6th iteration, it may possible that the travel time frequency distribution still shown some differences between the observed and calculated values. The K-adjustment factor can be applied to solve this problem. K-adjustment factor reflects the socio-economic conditions that can not be acounted well due to the limited independent variables used in gravity model. The experimental equation below is used to calculate K-adjustment factor.

$$K_{ij} = R_{ij} \frac{1 - X_{ij}}{1 - X_{ij} R_{ij}} \tag{6.7}$$

where R_{ij} = ration of observed trip to the gravity model result for the trips from zone *i* to zone *j*,

X_{ij} = ratio of origin-destination trips to the total origin-destination trips leaving zone *i*

Equation (6.7) is applied if 10 percent to 40 percent of the trip is leaving a zone. For other conditions, R_{ij} should be used as the K-adjustment factor [44, 45]. This equation is used in most transportation planning although it still not very clear and there are no perfect strategies for dealing with this K-adjustment factor. But, it's still believed, by the K-adjustment factor, the final trip distribution matrix can be determined.

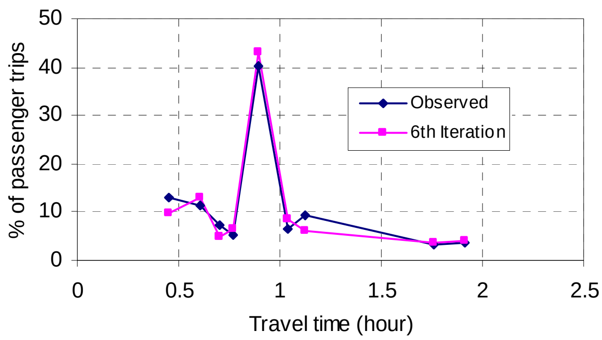


Figure 6.27 Travel time versus percentage of passenger trips

Additionally, root mean square error (RMSE) is statistical test that being use to test the model calibration. Figure 6.27 shows that after 6 iterations the calculated travel time frequency distribution and the observed travel time frequency distribution do fit well, with percent RMSE of 0.0861%. After applying the K-factor adjustment, the calculated travel time frequency distribution and the observed travel time frequency distribution match within 10%. At the same time, the RMSE decreased when K-factors were applied as shown in Table 6.50. The difference of the average travel time is 0.003% (below 10%).

6.5.3 Statistical Test for Gravity Model

From Table 6.50, it can be seen that the percent RMSE of 0.0861% (after 6th iteration) is small compared to 10%. Meanwhile, the overall RMSE is less than one passenger trip per day. Therefore, the gravity model is acceptable. Additionally, the difference of average travel time is 0.003%, quite small. The RMSE value between two iterations of less than 10% is used to test the tolerable difference.

Table 6.50 The statistical test (goodness of fit) for trips distribution

	Observed	2^{nd} Iteration	5^{th} Iteration	6^{th} Iteration
Overall RMSE (trips)	-	56.209	0.471	0.160
Percent RMSE (%)	-	23.484	0.2529	0.0861
Average travel time (hour)	1.028352	0.857882	0.856740	0.856713
Difference travel time (%)	-	16.577	0.009	0.003

According to above result and the explanation, the gravity model can be used appropriately for modeling bus passenger trip distribution based on the boarding and alighting passenger data as trip production and attraction, respectively. With the observed trip production, trip attraction and travel time, the zonal bus passenger trip distribution can be estimated. The gravity model is helpful for estimating bus passenger trip distribution in order to help in managing passenger trip, bus service operation and other related service.

In the gravity model calibration, the calibrated friction factors and the K-adjustment factor for the role of zonal socio-economic are obtained. The K-factor contribution is the zone-to-zone adjustment factor to achieve acceptable trip distribution matrix. By using RMSE value, the travel time frequency distribution curves of observed and calculated trip do fit well. And also, the calculated average travel time are good fit with observed values.

6.6 Summary

Both the Ipoh and Lumut bus station are end-to-end terminal which being dominant origin or destination. They are always crowded with high number of passengers boarding and alighting. A number of bus stop locations which have relative high number of passengers include Taman Maju, Bota Kanan, Ayer Tawar, Sitiawan and

Manjung. The average trip productivity in the corridor is 2,560 passengers per day, which distributed in Kinta (558 get on and 611 get off), Perak Tengah (635 get on and 531 get off) and Manjung (1,367 get on and 1,418 get off). Those numbers represent the potential demand of bus service. Ipoh and Lumut as the main start-end terminal are attractive destination in the Ipoh-Lumut corridor. Meanwhile, Ayer Tawar, Sitiawan and Taman Maju (Bandar Seri Iskandar) are now becoming more attractive and generative locations (greater town) with high growth in socio-economics development. For two-way trip, the top three stations which have more attractive and generative passengers per day are Ipoh bus station, Ayer Tawar and Lumut bus station. These areas indicated high level of socio-economic activities which generate high mobility of people demanding transportation facilities.

To attract more passengers using bus service (ridership) we should promote the use of bus by improving the quality of bus service. The strategy and analysis to improve quality of service are performed such as by changing frequency and capacity to attract increased demand or ridership. The change of frequency to become 3 buses per hour is preferable which is at headway of 20 minute, capacity of 44 seats and 15 buses per day available with load factor of 27%. The capacity is changed to become 25 seats in capacity, headway of 20 minute, frequency of 3 buses per hour, 15 buses per day and load factor of 59%. Frequency change is likely more preferable than the change in capacity due to the opportunity of raising load factor. Otherwise, at this load factor produce the comfort and will attract more bus users

The elasticity of transit demand is assessed with respect to ticket fare, fuel price, per capita income, service frequency, headway and travel time. The elasticity of transit demand with respect to price is not negative. The fact, a 1% increasing fare will still lead to a 0.101% increase in transit patronage. This happens because the increasing fare is not affecting people leaving from using public transport. The increase in fare from RM 6.50 to RM 8.40 (a 29.2% increase) doesn't reduce the patronage on this corridor, but number of 3,927 passengers per day in 2007 still increase to 4,030 in 2009 (a 2.62% increase). In terms of revenue, the benefits are as follows, RM 8,326.50 per day (optimistic scenario), RM 5,439 per day (Moderate scenario) and RM 2,054 per day (pessimistic scenario). In other words, there is no loss in revenue for the company or management due to the increasing fare. The increase of fare is still affordable by users as there is subsidiary from government, so that it doesn't significantly influence the demand of bus service.

The change of elasticity of fuel price is calculated with a 20% increase in fuel costs (from RM 1.60 /liter in 2007 to RM 1.92 /liter in 2009). Meanwhile, there is a 2.62% increase in bus patronage (from 3,927 passengers per day in 2007 to 4,030 passenger per day in 2009). The cross elasticity of demand to the fuel price is +0.142. It means that, a 1% increase in fuel price will lead to a 0.142% increase in transit patronage. The elasticity of income is +0.196. The demand increases by 0.196% as per capita income increases by 1%. The increase in income did not affect the decrease in transit use due to the ability in driving own car. The frequency elasticity is 0.036, meaning that a frequency rise of 1% will result in a 0.036% increase in transit ridership. In addition, the elasticity of headway is -0.093, whereas travel time elasticity is -4.057 (elastic). Thus, bus service demand responses sensitively by travel time change. Meanwhile, the elasticity of other factors are ticket fare (+0.101), fuel price (+0.142), per capita income (+0.196), service frequency (+0.073) and headway (-0.093) indicate inelastic factors in the change of bus service demand. In accordance with elasticity of reliability, the punctuality index (+2.64), waiting time (-3.21), service regularity (+4.62) and on-time performance (+1.15) are all categorized elastic factors.

According to the evaluation of bus service demand responses, it is revealed that bus service demand is mostly sensitive with the change in travel time. Consequently, it can be elaborated the effort on reducing travel time to attract more bus service demand. Meanwhile, some other factors such as ticket fare, fuel price, per capita income, service frequency and headway indicate as inelastic factors in the change of bus service demand. Therefore, based on the short-term period, the bus service demand change of current bus system is not sensitive with respect to the change in ticket fare, fuel price, per capita income, service frequency and headway. However, it may change based on those factors and some circumstances for long-term period.

Reliability factor such as punctuality index, waiting time, regularity and on-time performance indicate as being elastic factors to the sensitivity of bus service demand.

Therefore, the reliability of bus service is necessary to be improved for achieving viable and reasonable standard, in order to attract more bus service passengers.

The demand of public transport increase due to the level of service increases. Level of service is determined by variables such as reliability (punctuality, waiting time and regularity). Load factor (LF) is used to represent the level of demand. The increase of LF is achieved by the change of a number of factors such as increasing punctuality (percentage), decreasing waiting time, increasing level of service (LOS) and increasing regularity. Effect of LOS and regularity to load factor and number of passengers is studied. The load factor and number of passengers increase due to the increase in LOS and regularity. This proofs that bus is more attractive for users.

Gravity model is applied appropriately for modeling the bus passenger trip distribution based on the boarding and alighting passenger data. With data of boarding and alighting passenger assumed as trip production and trip attraction, respectively and observed travel time data, therefore, the zonal bus passenger trip distribution can be estimated. The gravity model is helpful for estimating bus passenger trip distribution in order to help in better management of passenger trip, bus service operation and other related service.

CHAPTER 7
CONCLUSIONS AND RECOMMENDATIONS

7.0 Overview

This chapter contains three parts, conclusions, recommendations and future research works. The conclusions are drawn based on factual findings discussed in the analysis and results section (chapters four, five and six), with regards to the objectives of this study. There are some proposed actions as a result of the discussion that are included in the recommendations section. Lastly, some future research works are highlighted.

7.1 Conclusions

Based on this study, the following conclusions can be drawn:

1. The measures of bus service characteristics such as vehicle and passenger characteristics, service frequency, load factor and lost time are identified from the analysis. A problem of long headway, as reflected by the low service frequency causing long waiting time, makes the existing bus system unattractive to passengers. A solution of shortening headway is assessed to shorten waiting time for attracting more passengers. Bus availability of 100% is very satisfactory although the load factor is low. By shortening headway, bus service attracts more people and the number of passengers and load factor increases. Based on the assessment, bus service characteristics are not viable compare to the requirement in World Bank standard, TCQSM standard and other referred standards. The World Bank standard is used for a general guidance to judge the viability of bus service whereas the existing bus service is more relevant to be categorized into the intercity bus service. In addition, a number of performance indicators have been analyzed extensively to evaluate the reliability of bus service such as on-time

performance, service regularity, punctuality index and expected average waiting time. Based on the on-time performance and service regularity of stage bus in mixed traffic, the results indicate that bus service has low on-time performance and low service regularity. According to punctuality index, the bus service is frequently bunching.

2. Regarding travel time assessment, three models are applied which are autoregressive integrated moving average (ARIMA), multiple linear regressions and statistica neural network (SNN). Using ARIMA model, the ARIMA(0,0,2) and ARIMA(0,0,1) models are appropriate to be applied for the bus travel time prediction for Ipoh to Lumut and Lumut to Ipoh direction, respectively. By multiple linear regressions, bus travel time is predicted appropriately by using independent variables such as distance, average speed and number of bus stop. Meanwhile, SNN model also proves that bus travel time is well predicted by using distance, average speed and number of bus stop. These models contribute to evaluate the bus travel time and to redesign the operational timetable for long distance bus service in the mixed traffic. The models can be applied to develop the information of bus travel time.

3. Based on the boarding and alighting of passengers, in Ipoh-Lumut corridor, there are a number of destinations with high potential demand such as Ipoh, Taman Maju, Bota Kanan, Ayer Tawar, Sitiawan, Manjung and Lumut, which are situated in three districts, namely Kinta, Perak Tengah and Manjung. This bus service demand presents the potential attractive and generative locations with high growth in socio-economics activities and development. The three top locations that attract and generate high passengers per day are Ipoh, Ayer Tawar and Lumut. The bus service demand is 2,560 passengers per day, which distributed in Kinta (22%), Perak Tengah (25%) and Manjung (53%).

4. To attract more passengers of bus service (ridership), the improvement of quality of bus service is required. The improvement strategies assessed include the changing of frequency, changing of capacity and improving the reliability of bus service. As the results, the change of frequency of three buses per hour is preferable than the change in capacity due to the high opportunity of rising load

factor in near future time. In addition, according to passenger's viewpoint bus service at this load factor is comfortable and is able to attract more bus users.

5. The sensitivity of bus service demand is assessed, first with respect to characteristics of bus service such as ticket fare, fuel price, per capita income, frequency, headway and travel time, and second with respect to reliability (punctuality, waiting time, service regularity and on-time performance). The elasticity of price (ticket fare) is +0.101, meaning that the increasing ticket fare does not affect people leaving from bus service, because ticket fare is still affordable for users as there is government's subsidy. The cross elasticity of fuel price is +0.142, meaning that a 1% increase in fuel price will lead to a 0.142% increase in passengers per day. The cross elasticity of per capita income is +0.196, thus demand increases by 0.196% as per capita income increases by 1%. The frequency elasticity is +0.073, meaning that a frequency rise of 1% will result in a 0.073% increase in demand. The elasticity of headway is -0.093. Travel time elasticity is -4.057, thus bus service demand responses sensitively by travel time change. Travel time is an elastic factor, whereas ticket fare, fuel price, per capita income, service frequency and headway are inelastic factors in the bus service demand. In accordance with reliability, the elasticity is obtained such as punctuality index (+2.637), waiting time (-3.208), service regularity (+4.624) and on-time performance (+1.150). Therefore, punctuality index, waiting time, service regularity and on-time performance are categorized into the elastic factors in the sensitivity of bus service demand.

6. By multiple linear regressions, the increasing reliability (punctuality, waiting time and regularity) leads to the increase of bus service demand. Load factor and number of passengers that representing the level of bus service demand will increase by a number of factors such as the increase in punctuality (percentage), decrease in waiting time, increase in level of service (LOS) and increase in service regularity.

7. In analyzing the bus service demand, gravity model is applied appropriately for modeling trip distribution of bus passenger based on the boarding and alighting passenger data. This model is useful for estimating the trip distribution of bus

passenger in order to help the better management of passenger trip and operation of bus service.

7.2 Recommendations

Some recommendations are highlighted in addressing the bus service improvement as follows:

1. The effort in improving bus service is a part of public transportation improvement in order to maximize people trip rather than vehicular traffic. This can reduce private cars use. Therefore, it is suggested the regulator to setup a rule and policy in promoting public transportation to encourage more people using a public transportation service.
2. It is recommended to improve the characteristics of bus system service addressing the issues on public transportation development in enhancing the efficiency of traffic, safety and environmental sustainability.
3. Shortening headway raises service frequency and provides shorter waiting time, so that bus service will be more attractive to passengers. The number of passengers and load factor increase as more people are attracted to short headway.
4. The bus service characteristics and performance indicators were not likely to meet the World Bank standard requirement. Therefore, in the local implementation, it's necessary to make adjustment upon the local resources, region potencies, assumptions and other limitations. Thus, consecutively, the operator/investor, regulator and customers/users are comprehensively considered in enhancing quality, efficiency and effectiveness of bus service delivery and operations.
5. In bus travel time prediction, there are limited three independent variables such as distance, average speed and number of bus stop. Therefore, in future research it is highly suggested for more independent variables studied.
6. It is recommended to change frequency to 3 buses per hour which is preferable at headway of 20 minute, capacity of 44 seats and 14 buses per day available with load factor of 28%. Frequency change is preferable than the change in capacity due to the high opportunity of raising load factor near future. And also, at this load factor, bus service produces comfort and will attract more bus users.

7.3 Future Research Works

Related to this study, there are number of research works which have a potential to be developed in the future. Those future research works include:

1. Extensive study can be performed to cover the evaluation and management of bus system service in both urban and rural areas.
2. Extensive study can be proposed for preparing standardization of bus service operation and framework evaluation of bus operators.
3. Extensive study can be developed for implementing new transportation technology such as vehicle tracking, passenger counting, ticketing, bus route modeling, intelligent transport system, etc.
4. Extensive study can be encouraged to improve the criteria, measurements, performance indicators, classification and decision making in public transportation development.

REFERENCES

[1] T. Litman, "Accessibility: Evaluating People's To Reach Desired Goods, Services And Activities," TDM Encyclopedia, Victoria Transport Policy Institute (VTPI), U.S.A. Available: http://www.vtpi.org/ [Retrieved on 30 April 2009], 2008.

[2] T. Litman, "Transport Diversity," TDM Encyclopedia, Victoria Transport Policy Institute (VTPI), U.S.A. Available: http://www.vtpi.org/ [Retrieved on 30 April 2009], 2006.

[3] N. Tyler, *Accessibility and the Bus System: From Concepts to Practice*. Accessibility Research Group, Centre for Transport Studies, University College London, UK: Thomas Telford, 2002.

[4] A. Frye, "Bus Travel – a Vital Link in the Chain of Accessible Transport," in *Proc. Bus and Coach 96*. Birmingham, UK, 1996.

[5] C. S. Papacostas and P. D. Prevendouros, *Transportation Engineering and Planning*, 3rd ed. Upper Saddle River, New Jersey 07458: Prentice-Hall, Inc., 2001.

[6] C. Benzie, "The Role of Public Transportation," Benzie County, Michigan, U.S.A., Available: http://www.benziebus.com/ [Retrieved on 1 June 2009], 2009.

[7] R. J. Shapiro, K. A. Hassett, and F. S. Arnold, "Conserving Energy and Preserving the Environment: The Role of Public Transportation," http://www.publictransportation.org/ [Retrieved on 25 June 2009], 2002.

[8] L. L. Higgins, M. D. Hickman, and C. A. Weatherby, "Role of Public Transportation Operations in Emergency Management: Research Report," Texas Transportation Institute, The Texas A&M University System, College Station, Texas 77843-3135, http://tti.tamu.edu/ [Retrieved on 25 June 2009], 1999.

[9] European Union, "The Role of Public Transport to Reduce Green House Gas Emissions and Improve Energy Efficiency," Position on the European Climate Change Programme and the Green Paper on Energy Efficiency, http://www.uitp.org/ [Retrieved on 25 June 2009], 2006.

[10] V. R. Vuchic, *Urban Transit: Operations, Planning, and Economics*. Hoboken, New Jersey: John Wiley & Sons, Inc., 2005.

[11] M. Roe, *Evaluation Methodologies for Transport Investment*. Avebury, Aldershot, England, 1987.

[12] J. T. Ball, *Civil Engineering PE Exam Depth Guide: Transportation Engineering*. New York, U.S.A.: McGraw-Hill, 2001.

[13] R. B. Diaz, M. Chang, G. Darido, M. Chang, E. Kim, D. Schneck, M. Hardy, J. Bunch, M. Baltes, D. Hinebaugh, L. Wnuk, and F. Silver, *Characteristics of Bus Rapid Transit for Decision-Making*: Project No: FTA-VA-26-7222-2004.1, Office of Research, Demonstration and Innovation, Federal Transit Administration, United States Department of Transportation, 2004.

[14] M. H. Jamaludin, "From Elephants to Buses," in *The New Sunday Times*. Ipoh, Perak, Malaysia, 2004.

[15] I. Anderson, *Ipoh World: Saving Yesterday for Tomorrow: An Interview with Dato' Tajudin Ali (A man of transport)*. Perak Roadways Company, Ipoh, Perak, 2005.

[16] Perak Roadways Sdn. Bhd., "Bus Service Schedule and Operational Data." Ipoh, Perak, Malaysia: Perak Roadways Sdn. Bhd., 2007.

[17] S. Arintono and S. Sebayang, "A Review of Bus Performance in Bandar Lampung," in *Proc. The Eastern Asia Society for Transportation Studies Conf.*, vol. 5. Tokyo: Eastern Asia Society for Transportation Studies (EASTS), 2005, pp. 404-413.

[18] J. H. Banks, *Introduction to Transportation Engineering*, 2nd ed. New York, America: McGraw Hill, 2002.

[19] T. T. Anh, Y. Tanaboriboon, and B. Q. Hung, "Analyzing of Bus Service in Hanoi - Vietnam," in *Proc. The Eastern Asia Society for Transportation Studies Conf.*, vol. 5. Tokyo: Eastern Asia Society for Transportation Studies (EASTS), 2005, pp. 352-362.

[20] A. Taniguchi, S. Fujii, and F. Hara, "Promotion of a Public Transport by Mobility Management and Verification of its Quantitative Effect: A Case Study for Community Bus in Obihiro City," in *Proc. The Eastern Asia Society for Transportation Studies Conf.*, vol. 5. Tokyo: Eastern Asia Society for Transportation Studies (EASTS), 2005, pp. 316-324.

[21] R. Sulistyorini, "The Performance of Urban Public Transportation System in Yogyakarta Special Region: Time Series Analysis 1988-1997," in *Department of Civil Engineering - Bachelor of Engineering*. Yogyakarta, Indonesia: Gadjah Mada University, 1997.

[22] C. J. Khisty and B. K. Lall, *Transportation Engineering: An Introduction*, 3rd ed. Upper Saddle River, New Jersey 07458: Prentice-Hall, Pearson Education, Inc., 2003.

[23] Transportation Research Board, "Transit Capacity and Quality of Service Manual-2nd Edition," TCRP Report 100, The National Academies Press. Transportation Research Board (TRB), Washington D.C., U.S.A. 2003.

[24] A. A. Wright and S. Thiriez, "Bus Service: Reducing Costs, Raising Standards," World Bank, Washington, D.C. 20433, U.S.A. Technical Paper Number 68: Urban Transport Series, 1987.

[25] Jabatan Kerja Raya, "A Guide on Geometric Design of Roads," Jabatan Kerja Raya (JKR), Cawangan Jalan Ibu Pejabat JKR, Jalan Sultan Salahuddin, 50582 Kuala Lumpur, Malaysia, 1986.

[26] Government of Malaysia, "Malaysia Urban Transport Planning Project: Ipoh Urban Transport Study," Government of Malaysia, Asian Development Bank, Halcrow Fox. 1995.

[27] Majlis Bandaraya Ipoh, "Draft of Perak Master Plan 2020," Majlis Bandaraya Ipoh (MBI), Perak, Malaysia. 2006.

[28] Highway Planning Unit, "Road Traffic Volume Malaysia (RTVM 2005)," Highway Planning Unit (HPU), Ministry of Works Malaysia, Kuala Lumpur, Malaysia. 2005.

[29] Y. J. Nakanishi, "Bus Performance Indicators: On-Time Performance and Service Regularity," *Transportation Research Record: J. Transportation Research Record No. 1571*, pp. 3-13, 1997.

[30] J. Strathman and J. Hopper, "Empirical Analysis of Bus Transit On-time Performnace," *J. Transportation Research Part A*, vol. 27A, pp. 93-100, 1993.

[31] M. Abkowitz and I. Engelstein, "Factors Affecting Running Time on Transit Routes," *J. Transportation Research Part A*, vol. 17A, pp. 107-113, 1983.

[32] H. P. Benn, "Bus Route Evaluation Standards," TCRP Synthesis of Transit Practice 10. The National Academy Press. Transport Research Board (TRB), Washington, D.C., U.S.A. 1995.

[33] X. Chen, L. Yu, Y. Zhang, and J. Guo, "Analyzing Urban Bus Service Reliability at the Stop, Route, and Network Levels," *J. Transportation Research Part A*, vol. 43, pp. 722-734, 2009.

[34] J. S. Park and S. Y. Kho, "A New Method to Determine Level of Service Criteria of Headway Adherence," in *TRB 2006 Ann. Meeting CD-ROM*. Washington, D.C., U.S.A.: The National Academy Press. Transport Research Board (TRB), 2006.

[35] S. Y. Kho, J. S. Park, Y. H. Kim, and E. H. Kim, "A Development of Punctuality Index for Bus Operation," *J. Eastern Asia Society of Transportation Studies*, vol. 6, pp. 492-504, 2005.

[36] S. K. J. Chang and C. L. Hsu, "Modeling Pasengger Waiting Time for Intermodal Transit Stations," *Transportation Research Record: J. Transportation Research Board No 1753*, pp. 69-75, 2001.

[37] E. E. Osuna and G. F. Newell, "General Strategies for an Idealized Public Transport System," *J. Transportation Science*, vol. 6, pp. 52-72, 1972.

[38] C. H. Oglesby and R. G. Hicks, *Highway Engineering*: John Wiley & Sons, 1982.

[39] A. Giannopoulus, *Bus Planning and Operation in Urban Areas, A Practical Guide*. New Castle upon Tyne, Great Britain: Athenaeum Press Ltd., 1989.

[40] P. Hills, T. Rhodes, R. Allsop, and A. Dick, *Roads and Traffic in Urban Areas*. 3 Lygon Place, London SW1W 0JS: The Institution of Highways and Transportation, The Department of Transport, 1987.

[41] S. Priyanto, "Experiment On Bus Lane Application in Yogyakarta," *Mag. Media Teknik*, vol. XXIV, 2002.

[42] J. G. Schoon, *Transportation Systems and Service Policy: A Project-Based Introduction*. New York, U.S.A.: Chapman & Hall, International Thomson Publishing, 1996.

[43] J. G. Schoon, "Transportation System Planning," Department of Civil Engineering, Northeastern University, Boston, MA. U.S.A. 1993.

[44] Department of Transportation, "Calibrating & Testing a Gravity Model for Any Size Urban Area," U.S. Dept. of Transportation (DOT), Federal Highway Administration, Washington, D.C., U.S.A. 1983.

[45] S. Mao and M. J. Demetsky, "Calibration of the Gravity Model for Truck Freight Flow Distribution," U.S. Dept. of Transportation (DOT), University Transportation Center, CTS Website Center for Transportation Studies, University of Virginia, Charlottesville, Virginia. 2002.

[46] Uidaho, "Travel Demand Forecasting: Theory and Concepts – The Gravity Model," in *Transportation Engineering Online Lab Manual*: University of Idaho, 2008.

[47] R. Sulistyorini, O. Z. Tamin, and A. Sjafruddin, "Pengembangan Model Kombinasi Gravity, Multinomial Logit dan Equilibrium Assignment," in *Proc. Simposium XII FSTPT*. Surabaya, Indonesia: FSTPT XII, Universitas Kristen Petra, 2009.

[48] A. J. Horowitz and D. D. Farmer, "A Critical Review of Statewide Travel Forecasting Practice," Available: http://my.execpc.com/ [Retrieved on 30 December 2009].

[49] O. Z. Tamin, *Perencanaan dan Pemodelan Transportasi*. Edisi II, Bandung, Indonesia: Penerbit ITB, 2000.

[50] W. A. Martin and N. A. McGuckin, "Travel Estimation Techniques for Urban Planning," Report 365, National Cooperative Highway Research Program. Transportation Research Board (TRB), Washington, D.C., U.S.A. 1998.

[51] P. C. Stubbs, W. J. Tyson, and M. Q. Dalvi, *Transportation Economics*. London: Allen & Unwin, 1980.

[52] T. E. Parody and D. Brand, "Forecasting Demand and Revenue for Transit Prepaid Pass and Fare Alternatives," *J. Transportation Research Record No. 719*, pp. 35-41, 1979.

[53] Unit Perancang Ekonomi Negeri, "Profil dan Data: Perak Darul Ridzuan," Unit Perancang Ekonomi Negeri Perak (UPEN), Pejabat Setiausaha Kerajaan Negeri Perak, 2004.

[54] Department of Statistics, *Population 2002 and Projections in 2008 Based on 2000 Population Census*. Perak: Dept. of Statistics Malaysia, 2008.

[55] Lembaga Pelesenan Kenderaan Perdagangan, "Commercial Vehicles Licensing Board Act 1987 (Act 334)," MECD: LPKP/20/S/656/1 Jld.2, Commercial Vehicle Licensing Board Peninsular Malaysia (LPKP), Malaysia, 2005.

[56] Department of Statistics, *Buku Laporan Penduduk Daerah Pentadbiran*. Perak: Dept. of Statistics Malaysia, 1980.

[57] Department of Statistics, *Buku Laporan Penduduk Negeri Perak*. Perak: Dept. of Statistics Malaysia, 1991.

[58] Department of Statistics, *Buku Taburan Penduduk Mengikut Kawasan Pihak Berkuasa Tempatan dan Mukim*. Perak: Dept. of Statistics Malaysia, 2000.

[59] Jabatan Pentadbiran Daerah Perak Tengah, "Income Distribution of Perak Tengah," Jabatan Pentadbiran Daerah Perak Tengah, Malaysia, 2006.

[60] Department of Statistics, *Transport and Communications Services Statistics*. Kuala Lumpur: Dept. of Statistics Malaysia, 2005.

[61] Department of Statistics, *Yearbook of Statistics*. Kuala Lumpur: Dept. of Statistics Malaysia, 2005.

[62] Department of Statistics, *State/District Data Bank*. Kuala Lumpur: Dept. of Statistics Malaysia, 2006.

[63] Jabatan Perdana Menteri, "Ninth Malaysia Plan 2006-2010," Jabatan Perdana Menteri, Malaysia, Kuala Lumpur 2005.

[64] Tourism Department, "Tourism Perak Malaysia," Tourism Malaysia, Available: http://www.cuti.com.my/ [Retrieved on 18 May 2006], 2006.

[65] Public Works Department, "The Length of Road and Railway," Public Works Dept., Malaysia, 2006.

[66] A. R. Hisham, "Hentian Bas Daif Jejas Imej Negara," in *Berita Harian: Surat & E-mel*. Kuala Lumpur, Malaysia, Available: http://www.bharian.com.my [Retrieved on 16 July 2008], 2008.

[67] Kuala Lumpur City Hall, "Kuala Lumpur Structure Plan 2020," Kuala Lumpur City Hall (KLCH), 2004.

[68] A. F. Sadullah, "The Institutional Framework of Public Transport Planning and Operation: R&D Support," Universiti Sains Malaysia, 2007.

[69] Kementerian Pembangunan Usahawan dan Kooperasi, "Lapuran Penemuan Jawatankuasa Kecil Bas Berhenti-Henti." Kuala Lumpur: Kementerian Pembangunan Usahawan dan Koperasi, Malaysia, 2005.

[70] Jabatan Perdana Menteri, "The National Key Result Areas: Improving Urban Public Transportation," Jabatan Perdana Menteri, Malaysia, 2009.

[71] J. Mohamad and A. T. Kiggundu, "The Rise of The Private Car in Kuala Lumpur, Malaysia: Assessing the Policy Options," *J. Int. Assoc. of Traffic and Safety Sci. (IATSS) Research*, vol. 31, pp. 69-77, 2007.

[72] R. Nekmat, "Public Transportation for Green Cities," presented at Green Cities International Conference: Putrajaya Urban Conference Series 2010, Perbadanan Putrajaya Complex, Putrajaya, Malaysia, 2010.

[73] Jabatan Keselamatan Jalan Raya, "Statistik Kemalangan Jalan Raya." Kuala Lumpur, Malaysia: Jabatan Keselamatan Jalan Raya (JKJR), 2008.

[74] Polis Diraja Malaysia, "Statistik Kemalangan Jalan Raya." Kuala Lumpur, Malaysia: Royal Malaysia Police (PDRM), 2008.

[75] Polis Diraja Malaysia, "Statistik Kemalangan Jalan Raya," Jabatan Ketenteraman Awam/Trafik, Ibu Pejabat Polis Kontinjen Perak, Polis Diraja Malaysia (PDRM), Perak, Malaysia. 2007.

[76] StatSoft, "STATISTICA (data analysis software system)," StatSoft, Inc., Available: www.statsoft.com [Retrieved on 5 January 2009), 2004.

[77] O. T. Keat, "Media Statement by Minister of Transport Malaysia-Bus Expressway Transit (BET) on 6 January 2010." Kuala Lumpur: Minister of Transport Malaysia, 2010.

[78] J. E. Evans, "Transit Scheduling and Frequency, Traveler Response to Transportation System Changes," TCRP Report 95, Chapter 9, The National Academy Press. Transportation Research Board (TRB), Washington, D.C., U.S.A. 2004.

[79] T. Litman, "Transportation Elasticities: How Prices and Other Factors Affect Travel Behavior," TDM Encyclopedia, Victoria Transport Policy Institute (VTPI), U.S.A. Available: www.vtpi.org/ [Retrieved on 30 April 2009], 2008.

GLOSSARY OF TERMS

The glossary of terms is compiled by referring a number of relevant resources that consists of World Bank Technical Paper Number 68 (1987), TCRP Synthesis 10 (TRB, 1995), TCRP 100: TCQSM (2003), Khisty and Lall (2003), and Papacostas and Prevendouros (2001).

Average running time – The average time vehicles are in motion while traversing a highway segment of given length, excluding stopped-time delay, in seconds per vehicle or minutes per vehicle.

Average stopped-time delay – The total time vehicles are stopped in an intersection approach or lane group during a specified time interval divided by the volume departing from the approach or lane group during the same time period, in seconds per vehicle.

Average total delay – The total additional travel time experienced by drivers, passengers, or pedestrians as a result of control measures and interaction with other users of the facility divided by the volume departing from the corresponding cross section of the facility.

Average travel speed – The average speed of a traffic stream computed as the length of a highway segment divided by the average travel time of vehicles traversing the segment, in kilometers per hour.

Average travel time – The average time spent by vehicles traversing a highway segment of given length, including all stopped-time delay, in seconds per vehicle or minutes per vehicle.

Bus hours - The total hours of travel by bus during service or operation time (synonym = vehicle hours).

Bus kilometers - The total kilometers of travel by bus along service or operation distance (synonym = vehicle kilometers).

Capacity – The maximum rate of flow at which persons or vehicles can be reasonably expected to traverse a point or uniform segment of a lane or roadway during a specified time period under prevailing roadway, traffic, and control conditions, usually expressed as vehicles per hour or persons per hour.

Central Business District (CBD) - The traditional downtown retail, trade, and commercial area of a city of an area of very high land valuation, traffic flow, and concentration of retail business offices, theater, hotels and services.

Delay – Additional travel time experienced by a driver, passenger, or pedestrian beyond what would reasonably be desired for a given trip.

Demand volume – The traffic volume expected to desire service past a point or segment of the highway system at some future time, or the traffic currently arriving or desiring service past such a point, usually expressed as vehicles per hour.

Density – The number of vehicles occupying a given length of lane or roadway averaged over time, usually expressed as vehicles per kilometer or vehicles per kilometer per lane.

Headway - The scheduled time interval between any two revenue vehicles operating in the same direction on a route Headways may be LOAD driven, that is, developed on the basis of demand and loading standards or, POLICY based, i.e., dictated by policy decisions such as service every 30 minutes during the peak periods and every 60 minutes during the base period (synonym = frequency schedule vehicle spacing).

Headway – The time between two successive vehicles in a traffic lane as they pass a point on the roadway, measured from front bumper to front bumper, in seconds.

Layover time - Layover time serves two major functions: recovery time for the schedule to ensure on-time departure for the next trip and, in some systems, operator rest or break time between trips. Layover time is often determined by labor agreement, requiring “off-duty” time after a certain amount of driving time (synonym = recovery time)

Level of service (LOS) – A qualitative measure describing operational conditions within a traffic stream, generally described in terms of such factors as speed and travel time, freedom to maneuver, traffic interruptions, comfort and convenience, and safety. LOS is a way to measure QOS. There are six ranges of values for a measure, grades from A to F.

Maximum load point - The location(s) along a route where the vehicle passenger load is the greatest. The maximum load point(s) generally differ by direction and may also be unique to each of the daily operating periods. Long or complex routes may have multiple maximum load points.

Passenger car units (p.c.u) – Passengers car unit is obtained by converting the various classes of vehicles by using conversion factors. It is used for stating the capacity of traffic.

Passenger kilometers - A measure of service utilization which represents the cumulative sum of the distances ridden by each passenger. It is normally calculated by summation of the passenger load times the distance between individual bus stops. For example, ten passengers riding in a transit vehicle for two kilometers equals 20 passenger kilometers.

Peak hour/peak period - The period with the highest ridership during the entire service day, generally referring to either the peak hour or peak several hours (peak period), synonym = commission hour.

Quality of service (QOS) - The overall measured or perceived performance of transit service from the passenger’s point-of-view.

Recovery time - Recovery time is district from layover, although they are usually combined together. Recovery time is a planned time allowance between the arrival time of a just completed trip and the departure time of the next trip in order to allow the route to return to schedule if traffic, loading, or other conditions have made the trip arrive late Recovery time is considered as reserve running time and typically, the operator will remain on duty during the recovery period.

Route - An established series of streets and turns connecting two terminus locations (synonym = line).

Running time - The time assigned for the movement of a revenue vehicle over a route, usually done on a [route] segment basis by various time of day (synonym = travel time).

Schedule - From the transit agency (not the public time table), a document that, at a minimum, shows the time of each revenue trip through the designated time points Many properties include additional information such as route descriptions, deadhead times and amounts, interline information, run numbers, block numbers, etc. (synonym = headway, master schedule, timetable, operating schedule, recap/supervisor’s guide).

Service span - The span of hours over which service is operated, e g., 6 a.m. to 10 p m or 24 hr (owl) Service span often varies by weekday, Saturday, or Sunday (synonym = span of service, service day).

Space mean speed – The average speed of the traffic stream computed as the length of the highway segment divided by the average travel time of vehicles to traverse the segment; average travel speed; in kilometers per hour.

Spacing – The distance between two successive vehicles in a traffic lane measured from front bumper to front bumper, in meters.

Speed – A rate of motion expressed as distance per unit time.

Time mean speed – The arithmetic average of individual vehicle speeds passing a point on a roadway or lane, in kilometers per hour.

Total kilometers - The total kilometers includes revenue, deadhead, and yard (maintenance and servicing) kilometers.

Travel time - The time allowed for an operator to travel between the garage and a remote relief point (synonym = relief time, travel allowance).

Trip - The one-way operation of a revenue vehicle between two terminus points on a route Trips are generally noted as inbound, outbound, eastbound, westbound, etc to identify directionality when being discussed or printed (synonym = journey, one-way trip).

v/c ratio – The ratio of demand flow rate to capacity for a traffic facility.

Volume – The number of persons or vehicles passing a point on a lane, roadway, or other traffic way during some time interval, often taken to be 1 hr, expressed in vehicles.

APPENDIX A:

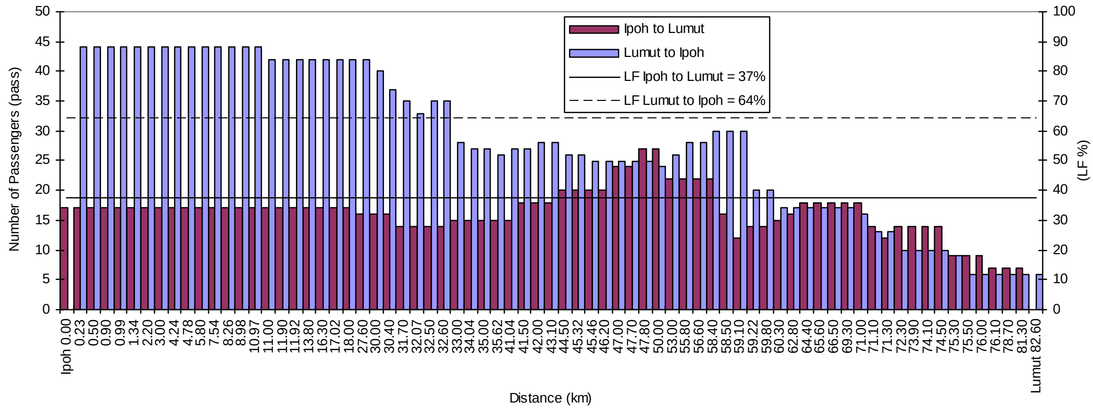
Data Compilation

A.1. Data collection time table

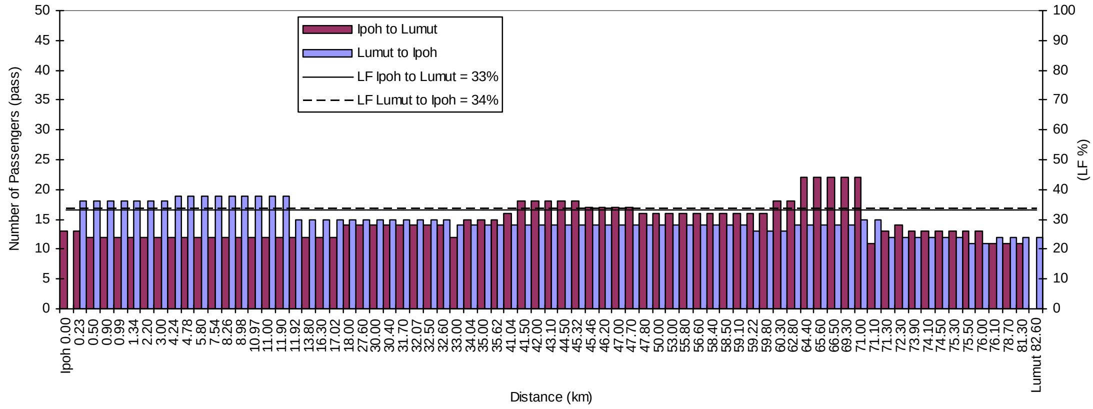
No	Categories	Day	Typical Day	Time	Direction	Date
1	Preliminary					
	a. Traffic survey	Tue	Workday	Morning, midday, afternoon	Both direction	7-Nov-06
	b. Bus service frequency	Tue	Workday	Morning, midday, afternoon	Both direction	7-Nov-06
	c. Road geometry and tracking the location	Thu	Workday	08.00-19.00	Both direction	16-Nov-06
	d. On board survey	Sun	Weekend	09:38-11:19	Both direction	19-Nov-06
		Tue	Workday	11.55-13.41	Both direction	28-Nov-06
2	On board survey					
	Full one day	Wed	Workday	07.00-20.30	Both direction	24-Jan-07
3	On board survey					
	One week	Mon	Workday	11.00-15.00	Both direction	12-Feb-07
	Feb	Tue	Workday	11.00-15.00	Both direction	13-Feb-07
		Wed	Workday	11.00-15.00	Both direction	14-Feb-07
		Thu	Workday	11.00-15.00	Both direction	15-Feb-07
		Fri	Workday	11.00-15.00	Both direction	16-Feb-07
		Sat	Weekend	11.00-15.00	Both direction	17-Feb-07
		Sun	Weekend	11.00-15.00	Both direction	18-Feb-07
4	On board survey (one year)					
	Jan	Thu	Workday	11.00-15.00	Both direction	25-Jan-07
		Sat	Weekend	11.00-15.00	Both direction	27-Jan-07
	Feb	Wed	Workday	11.00-15.00	Both direction	14-Feb-07
		Sun	Weekend	11.00-15.00	Both direction	11-Feb-07
	Mar	Wed	Workday	11.00-15.00	Both direction	14-Mar-07
		Sun	Weekend	11.00-15.00	Both direction	18-Mar-07
	Apr	Wed	Workday	11.00-15.00	Both direction	11-Apr-07
		Sat	Weekend	11.00-15.00	Both direction	14-Apr-07
	May	Wed	Workday	11.00-15.00	Both direction	9-May-07
		Sat	Weekend	11.00-15.00	Both direction	12-May-07
	Jun	Wed	Workday	11.00-15.00	Both direction	6-Jun-07
		Sat	Weekend	11.00-15.00	Both direction	2-Jun-07
	Jul	Wed	Workday	11.00-15.00	Both direction	25-Jul-07
		Sat	Weekend	11.00-15.00	Both direction	29-Jul-07
	Aug	Wed	Workday	11.00-15.00	Both direction	22-Aug-07
		Sat	Weekend	11.00-15.00	Both direction	18-Aug-07
	Sep	Wed	Workday	11.00-15.00	Both direction	19-Sep-07
		Sat	Weekend	11.00-15.00	Both direction	22-Sep-07
	Oct	Wed	Workday	11.00-15.00	Both direction	31-Oct-07
		Sat	Weekend	11.00-15.00	Both direction	27-Oct-07
	Nov	Tue	Workday	11.00-15.00	Both direction	6-Nov-07
		Sat	Weekend	11.00-15.00	Both direction	3-Nov-07
	Dec	Wed	Workday	11.00-15.00	Both direction	5-Dec-07
		Sat	Weekend	11.00-15.00	Both direction	8-Dec-07

A.2. Preliminary Survey

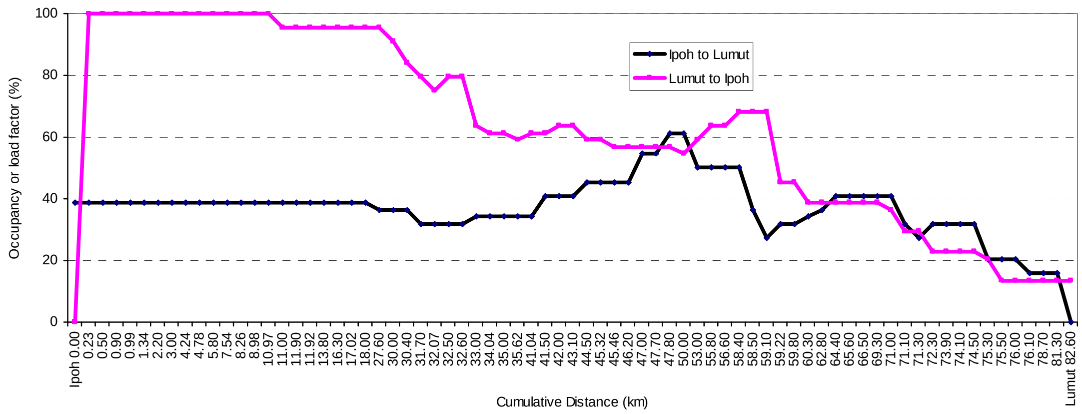
A.2.1. Typical loading profile during weekend



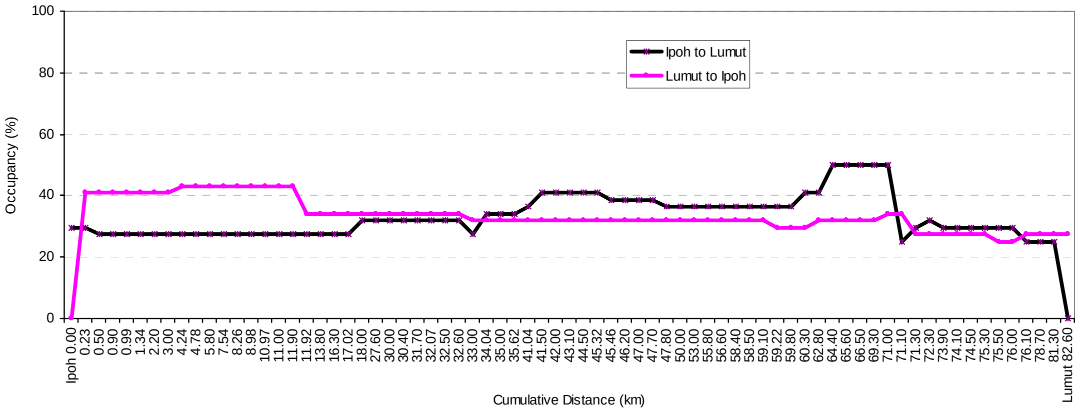
A.2.2. Typical loading profile during workday



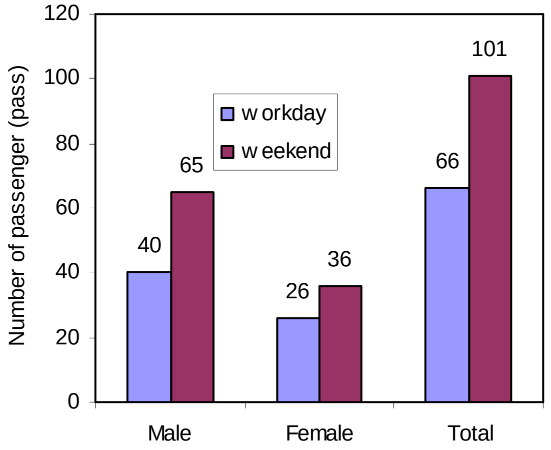
A.2.3. Typical bus occupancy (load factor) during weekend



A.2.4. Typical bus occupancy (load factor) during workday



A.2.5. Typical male and female composition of passengers



A.3. Departure Time Data

No	Location	Scheduled Duration (minute)	Distance (km)	Jan Thu 25-Jan-07 workday	Sat 27-Jan-07 weekend	Feb Wed 14-Feb-07 workday	Sun 11-Feb-07 weekend	Mar Wed 14-Mar-07 workday	Sun 18-Mar-07 weekend	Apr Wed 11-Apr-07 workday	Sat 14-Apr-07 weekend	May Wed 9-May-07 workday	Sat 12-May-07 weekend	Jun Wed 6-Jun-07 workday	Sat 2-Jun-07 weekend
1	Ipoh (Perak Roadways)	0	0	11:09 AM	11:12 AM	11:15 AM	11:11 AM	11:21 AM	11:05 AM	11:04 AM	11:02 AM	11:15 AM	11:02 AM	11:06 AM	11:09 AM
	Menglembu	6	4.3	-	-	-	-	-	-	-	-	-	-	-	11:18 AM
2	Medan Lahat Baru	12	8.7	-	-	-	-	-	-	-	11:20 AM	11:46 AM	-	-	11:24 AM
	Pengkalan	15	11.5	-	-	-	-	-	-	-	11:20 AM	-	-	-	11:29 AM
	Seputeh	24	18.2	-	-	-	-	-	-	-	-	-	-	-	-
3	Taman Seputeh Perdana	26	19.6	-	-	11:37 AM	-	-	-	-	-	-	-	-	11:37 AM
	Tronoh	32	24.1	-	-	-	-	-	-	-	-	-	-	-	11:33 AM
4	UTP	37	27.6	-	11:46 AM	-	11:43 AM	11:55 AM	11:34 AM	-	11:37 AM	-	11:34 AM	-	11:44 AM
5	Taman Maju / Seri Iskandar Bus Terminal	40	30.2	11:50 AM	11:50 AM	11:46 AM	11:46 AM	11:58 AM	11:37 AM	11:41 AM	11:40 AM	11:49 AM	11:36 AM	11:40 AM	11:47 AM
6	UiTM / Perak Tengah	44	32.9	11:53 AM	11:53 AM	11:51 AM	11:51 AM	12:00 PM	11:41 AM	-	11:44 AM	11:53 AM	11:40 AM	-	11:52 AM
7	Bota Kanan	55	41.5	12:04 PM	12:08 PM	12:02 PM	12:00 PM	12:11 PM	11:51 AM	11:51 AM	11:56 AM	12:02 PM	11:50 AM	11:51 AM	12:03 PM
8	Bota Kiri (junction)	57	43.1	12:08 PM	12:12 PM	12:04 PM	-	12:18 PM	11:55 AM	-	12:00 PM	12:05 PM	-	-	12:08 PM
9	Titi Gantong (Jabatan Pertanian)	61	45.6	12:11 PM	12:15 PM	-	-	12:20 PM	11:57 AM	-	12:04 PM	-	-	-	12:13 PM
10	APL Industry	70	52.9	12:20 PM	-	-	-	12:29 PM	12:07 PM	-	12:16 PM	12:16 PM	-	-	12:24 PM
	Junction to Pt. Remis	75	56.1	-	-	-	-	-	-	-	-	-	-	-	-
11	Ayer Tawar (Pejabat Polis)	79	59.1	12:31 PM	12:40 PM	12:24 PM	12:24 PM	12:38 PM	12:15 PM	12:16 PM	12:23 PM	12:24 PM	12:15 PM	12:18 PM	12:36 PM
12	Sitiawan (Pos Office)	95	71	12:49 PM	12:55 PM	12:40 PM	12:39 PM	12:55 PM	12:28 PM	12:33 PM	12:39 PM	12:44 PM	12:29 PM	12:30 PM	12:53 PM
13	The Store	95	71.5	12:53 PM	12:59 PM	12:42 PM	12:43 PM	12:59 PM	12:31 PM	12:34 PM	12:41 PM	12:45 PM	-	12:37 PM	12:56 PM
14	Manjung Bus Station	100	75.3	1:02 PM	1:06 PM	12:54 PM	12:52 PM	1:08 PM	12:37 PM	12:45 PM	12:51 PM	12:52 PM	12:40 PM	12:48 PM	1:05 PM
15	Lumut	110	82.6	1:12 PM	1:21 PM	1:05 PM	1:03 PM	1:21 PM	12:47 PM	12:58 PM	1:04 PM	1:03 PM	12:52 PM	12:59 PM	1:16 PM
			Duration (hour):	2.05	2.15	1.83	1.87	2.00	1.70	1.90	2.03	1.80	1.83	1.88	2.12
			Minute:	123	129	110	112	120	102	114	122	108	110	113	127
15	Lumut	0	82.6	1:15 PM	1:26 PM	1:10 PM	1:05 PM	2:07 PM	12:56 PM	1:01 PM	1:07 PM	1:08 PM	1:05 PM	2:05 PM	1:20 PM
14	Manjung Bus Station	10	75.3	1:25 PM	-	1:27 PM	1:16 PM	2:19 PM	1:05 PM	1:12 PM	1:22 PM	1:20 PM	1:17 PM	2:15 PM	-
13	The Store	15	71.5	1:34 PM	-	1:33 PM	1:26 PM	2:31 PM	1:16 PM	1:20 PM	1:32 PM	1:31 PM	1:27 PM	2:26 PM	1:39 PM
12	Sitiawan (Pos Office)	15	71	1:36 PM	1:42 PM	1:35 PM	1:28 PM	2:33 PM	1:19 PM	1:24 PM	1:35 PM	1:36 PM	1:29 PM	2:30 PM	1:45 PM
11	Ayer Tawar (Pejabat Polis)	31	59.1	1:56 PM	1:56 PM	1:55 PM	1:43 PM	2:56 PM	1:32 PM	1:44 PM	1:50 PM	1:54 PM	1:42 PM	2:47 PM	1:59 PM
	Junction to Pt. Remis	35	56.1	-	-	-	-	-	-	-	-	-	-	-	-
10	APL Industry, Junction to beruas	40	52.9	-	-	-	1:52 PM	3:06 PM	1:42 PM	1:58 PM	-	2:03 PM	1:54 PM	-	-
9	Titi Gantong (Jabatan Pertanian)	49	45.6	2:12 PM	2:17 PM	2:12 PM	1:58 PM	3:13 PM	1:48 PM	2:07 PM	2:06 PM	-	-	3:02 PM	-
8	Bota Kiri (junction)	53	43.1	2:15 PM	2:21 PM	2:15 PM	-	3:19 PM	-	2:10 PM	2:09 PM	2:13 PM	-	-	2:17 PM
7	Bota Kanan	55	41.5	2:20 PM	2:26 PM	2:19 PM	2:06 PM	3:23 PM	1:58 PM	2:14 PM	2:13 PM	2:18 PM	2:10 PM	3:12 PM	2:22 PM
6	UiTM / Perak Tengah	66	32.9	2:33 PM	2:40 PM	2:32 PM	-	3:39 PM	2:08 PM	2:33 PM	2:28 PM	2:34 PM	2:21 PM	-	2:32 PM
5	Taman Maju / Seri Iskandar Bus Terminal	70	30.2	2:39 PM	2:43 PM	2:35 PM	2:20 PM	3:43 PM	2:12 PM	2:37 PM	2:33 PM	2:38 PM	2:25 PM	3:22 PM	2:36 PM
4	UTP	73	27.6	2:42 PM	2:47 PM	2:40 PM	2:24 PM	3:47 PM	2:15 PM	2:41 PM	-	2:42 PM	2:28 PM	-	2:39 PM
	Tronoh	78	24.1	-	-	-	-	-	-	-	-	-	-	3:31 PM	-
3	Taman Seputeh Perdana	84	19.6	-	-	-	-	-	-	-	-	-	-	-	-
	Seputeh	86	18.2	-	-	-	-	3:57 PM	-	-	-	-	-	-	2:47 PM
	Pengkalan	95	11.5	-	-	-	-	-	-	-	-	2:58 PM	-	-	-
2	Medan Lahat Baru	98	8.7	-	-	-	2:42 PM	4:12 PM	-	-	2:55 PM	-	-	-	-
	Menglembu	104	4.3	-	-	-	-	-	2:43 PM	-	-	-	-	-	-
1	Ipoh (Perak Roadways)	110	0	3:20 PM	3:24 PM	3:15 PM	2:55 PM	4:26 PM	2:49 PM	3:16 PM	3:09 PM	3:14 PM	3:03 PM	4:00 PM	3:10 PM
			Duration (hour):	2.08	1.97	2.08	1.83	2.32	1.88	2.25	2.03	2.10	1.97	1.92	1.83
			Minute:	125	118	125	110	139	113	135	122	126	118	115	110
								*							
	Note:		Traveltime:	248	247	235	222	259	215	249	244	234	228	228	237
	Design speed (km/jam) =	45													

*) Bus stopped due to engine problem at Sitiawan (ACA 1100), passenger was moved to ACP 3100

**) Bus departed from Ipoh too late at 11:27 (scheduled 11:00), Informal ticket counter at Sitiawan, Bus did not enter Manjung Bus station

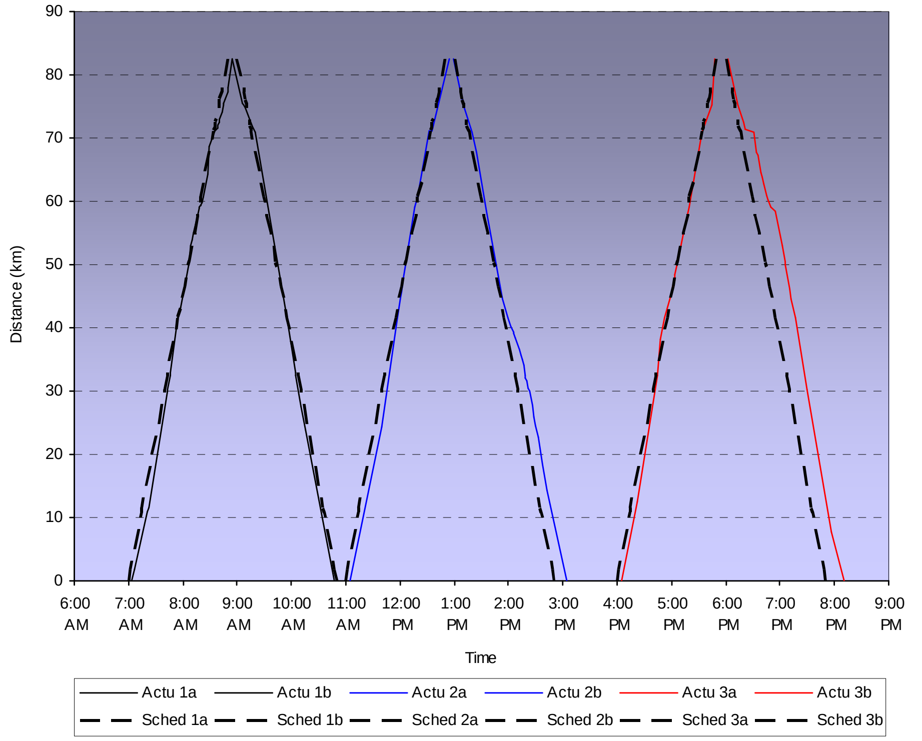
A.3 Departure Time Data (continued)

No	Location	Scheduled Duration (minute)	Distance (km)	Jul Wed 25-Jul-07 workday	Sat 29-Jul-07 weekend	Aug Wed 22-Aug-07 workday	Sat 18-Aug-07 weekend	Sep Wed 19-Sep-07 workday	Sat 22-Sep-07 weekend	Oct Wed 31-Oct-07 workday	Sat 27-Oct-07 weekend	Nop Tue 6-Nov-07 workday	Sat 3-Nov-07 weekend	Dec Wed 5-Dec-07 workday	Sat 8-Dec-07 weekend
1	Ipoh (Perak Roadways)	0	0	11:06 AM	11:04 AM	11:07 AM	11:04 AM	11:14 AM	11:27 AM	11:03 AM	11:07 AM	11:06 AM	11:12 AM	11:19 AM	12:00 PM
	Menglembu	6	4.3	-	-	-	-	-	-	-	-	-	-	11:28 AM	-
2	Medan Lahat Baru	12	8.7	-	-	-	-	-	-	-	-	-	-	-	-
	Pengkalan	15	11.5	-	-	-	-	-	-	-	-	-	-	-	-
	Seputeh	24	18.2	-	-	-	-	-	-	-	-	-	-	-	-
3	Taman Seputeh Perdana	26	19.6	-	-	-	-	-	-	-	-	11:32 AM	-	-	-
	Tronoh	32	24.1	-	-	-	-	-	-	11:32 AM	-	-	11:39 AM	-	-
4	UTP	37	27.6	-	-	-	-	-	11:58 AM	-	-	11:39 AM	11:43 AM	11:50 AM	12:31 PM
5	Taman Maju / Seri Iskandar Bus Terminal	40	30.2	11:42 AM	11:39 AM	11:42 AM	11:39 AM	11:54 AM	12:01 PM	11:37 AM	11:39 AM	11:41 AM	11:47 AM	11:52 AM	12:34 PM
6	UiTM / Perak Tengah	44	32.9	-	11:43 AM	-	11:43 AM	12:01 PM	12:06 PM	11:41 AM	11:44 AM	11:46 AM	-	-	12:40 PM
7	Bota Kanan	55	41.5	11:57 AM	11:53 AM	11:52 AM	11:56 AM	12:13 PM	12:16 PM	11:50 AM	11:55 AM	11:55 AM	12:01 PM	12:05 PM	12:51 PM
8	Bota Kiri (junction)	57	43.1	12:00 PM	-	11:56 AM	-	12:16 PM	12:21 PM	-	12:00 PM	12:03 PM	-	12:09 PM	12:55 PM
9	Titi Gantong (Jabatan Pertanian)	61	45.6	-	12:02 PM	-	12:04 PM	12:20 PM	-	11:57 AM	12:05 PM	12:05 PM	12:08 PM	12:12 PM	1:00 PM
10	APL Industry	70	52.9	12:12 PM	-	12:12 PM	-	12:29 PM	-	-	12:12 PM	12:16 PM	12:18 PM	-	-
	Junction to Pt. Remis	75	56.1	-	-	-	-	-	12:51 PM	-	12:18 PM	12:22 PM	12:21 PM	12:26 PM	-
11	Ayer Tawar (Pejabat Polis)	79	59.1	12:18 PM	12:20 PM	12:33 PM	12:25 PM	12:40 PM	12:56 PM	12:17 PM	12:22 PM	12:25 PM	12:26 PM	12:29 PM	1:15 PM
12	Sitiawan (Pos Office)	95	71	12:33 PM	12:36 PM	12:48 PM	12:42 PM	12:56 PM	1:11 PM	12:35 PM	12:41 PM	12:46 PM	12:45 PM	12:49 PM	1:35 PM
13	The Store	95	71.5	12:37 PM	12:40 PM	12:51 PM	12:46 PM	12:59 PM	1:14 PM	12:37 PM	12:44 PM	12:48 PM	12:47 PM	12:53 PM	1:38 PM
14	Manjung Bus Station	100	75.3	12:45 PM	12:49 PM	12:58 PM	12:54 PM	1:09 PM	1:24 PM	12:46 PM	12:51 PM	12:56 PM	12:57 PM	1:00 PM	1:46 PM
15	Lumut	110	82.6	12:55 PM	1:00 PM	1:08 PM	1:04 PM	1:20 PM	1:36 PM	12:55 PM	1:00 PM	1:09 PM	1:10 PM	1:12 PM	1:58 PM
			Duration (hour):	1.82	1.93	2.02	2.00	2.10	2.15	1.87	1.88	2.05	1.97	1.88	1.97
			Minute:	109	116	121	120	126	129	112	113	123	118	113	118
15	Lumut	0	82.6	12:59 PM	1:10 PM	1:11 PM	1:11 PM	2:06 PM	2:20 PM	2:11 PM	1:04 PM	1:13 PM	2:08 PM	3:13 PM	3:05 PM
14	Manjung Bus Station	10	75.3	1:13 PM	1:21 PM	1:22 PM	1:22 PM	2:17 PM	-	-	1:14 PM	-	2:20 PM	3:22 PM	3:17 PM
13	The Store	15	71.5	1:20 PM	1:32 PM	1:32 PM	1:31 PM	2:27 PM	-	2:30 PM	-	1:29 PM	2:28 PM	3:31 PM	3:30 PM
12	Sitiawan (Pos Office)	15	71	1:24 PM	1:36 PM	1:35 PM	1:35 PM	2:28 PM	2:42 PM	2:32 PM	1:24 PM	1:32 PM	2:31 PM	3:35 PM	3:35 PM
11	Ayer Tawar (Pejabat Polis)	31	59.1	1:39 PM	1:53 PM	1:50 PM	1:51 PM	2:42 PM	2:58 PM	2:48 PM	1:41 PM	1:50 PM	2:48 PM	3:50 PM	3:53 PM
	Junction to Pt. Remis	35	56.1	-	-	-	-	-	3:07 PM	-	1:46 PM	-	-	3:59 PM	-
10	APL Industry, Junction to beruas	40	52.9	-	2:06 PM	1:59 PM	2:01 PM	2:52 PM	3:13 PM	2:57 PM	-	1:59 PM	2:56 PM	4:04 PM	4:01 PM
9	Titi Gantong (Jabatan Pertanian)	49	45.6	1:57 PM	2:18 PM	2:07 PM	2:10 PM	3:00 PM	3:22 PM	-	2:03 PM	2:09 PM	3:08 PM	4:18 PM	4:09 PM
8	Bota Kiri (junction)	53	43.1	2:01 PM	-	-	-	3:03 PM	3:27 PM	3:15 PM	-	-	3:11 PM	4:22 PM	4:14 PM
7	Bota Kanan	55	41.5	2:05 PM	2:24 PM	2:15 PM	2:17 PM	3:07 PM	3:31 PM	3:18 PM	2:12 PM	2:16 PM	3:15 PM	4:28 PM	4:18 PM
6	UiTM / Perak Tengah	66	32.9	2:22 PM	2:37 PM	2:29 PM	2:28 PM	-	-	-	2:24 PM	2:31 PM	-	4:39 PM	4:32 PM
5	Taman Maju / Seri Iskandar Bus Terminal	70	30.2	2:26 PM	2:44 PM	2:32 PM	2:33 PM	3:19 PM	3:43 PM	3:30 PM	2:28 PM	2:36 PM	3:27 PM	4:46 PM	4:35 PM
4	UTP	73	27.6	2:30 PM	-	2:34 PM	-	-	-	3:33 PM	2:32 PM	-	3:30 PM	4:54 PM	4:39 PM
	Tronoh	78	24.1	2:35 PM	-	-	-	3:28 PM	-	-	-	2:45 PM	-	4:56 PM	4:41 PM
3	Taman Seputeh Perdana	84	19.6	-	-	-	-	-	-	3:40 PM	-	-	-	-	4:46 PM
	Seputeh	86	18.2	-	-	2:44 PM	-	-	-	-	-	-	-	-	-
	Pengkalan	95	11.5	-	3:04 PM	-	2:52 PM	3:43 PM	-	-	-	-	-	-	-
2	Medan Lahat Baru	98	8.7	2:54 PM	-	-	-	-	-	-	-	-	-	-	-
	Menglembu	104	4.3	-	3:09 PM	-	-	-	4:14 PM	-	3:02 PM	-	-	-	-
1	Ipoh (Perak Roadways)	110	0	3:07 PM	3:22 PM	3:08 PM	3:09 PM	3:58 PM	4:22 PM	4:06 PM	3:08 PM	3:14 PM	4:04 PM	5:28 PM	5:12 PM
			Duration (hour):	2.13	2.20	1.95	1.97	1.87	2.03	1.92	2.07	2.02	1.93	2.25	2.12
			Minute:	128	132	117	118	112	122	115	124	121	116	135	127
									* *						
	Note:		Traveltime:	237	248	238	238	238	251	227	237	244	234	248	245
	Design speed (km/jam) =	45													

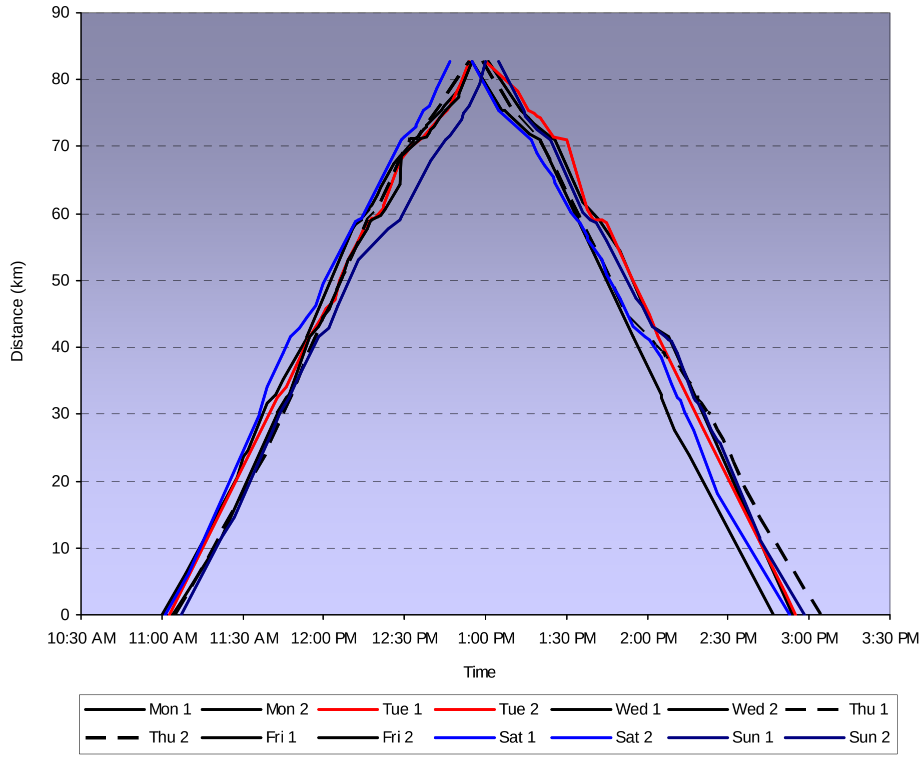
*) Bus stopped due to engine problem at Sitiawan (ACA 1100), passenger was moved to ACP 3100

**) Bus departed from Ipoh too late at 11:27 (scheduled 11:00), Informal ticket counter at Sitiawan, Bus did not enter Manjung Bus station

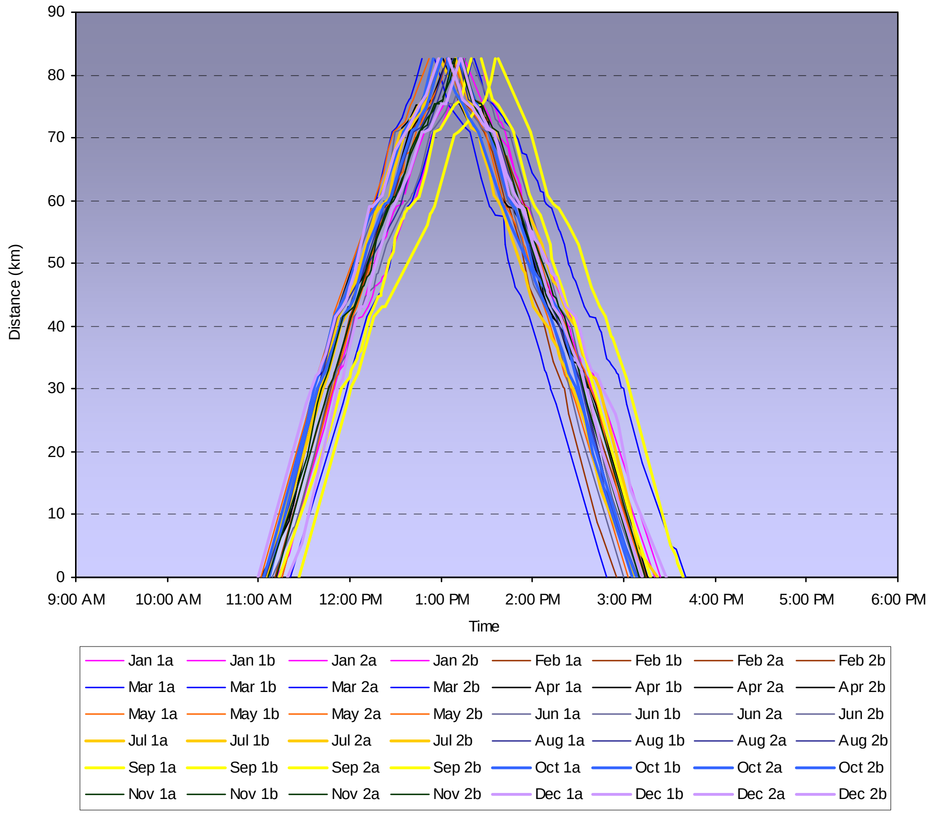
A.4. Full one day bus trajectory



A.5. One week bus trajectory



A.6. One year bus trajectory



A.7. Data compilation from GPS

A.7.1. Trip computer on-board survey

Month	Typical day	Day	Date	Trip odom km	Moving time hours	min	Stopped min	seconds	Odometer km	Speed	Max speed km/h	Moving avg km/h	Overall average km/h
Jan	workday	Thu	25-Jan-07	156	3	31	28	45	156.0		5529	44.2	38.9
	weekend	Sat	27-Jan-07	156	3	31	28	45	156.0		5529	44.2	38.9
Feb	workday	Wed	14-Feb-07	156	3	31	28	45	156.0		5529	44.2	38.9
	weekend	Sun	11-Feb-07	160	3	10	25	52	159.6		5529	50.2	44.2
Mar	workday	Wed	14-Mar-07	163	3	43	36	35	163.0		5529	43.7	37.5
	weekend	Sun	18-Mar-07	162	3	17	28	40	161.9		5529	49.2	42.9
Apr	workday	Wed	11-Apr-07	160	3	29	47	10	160.0		5529	45.9	37.5
	weekend	Sat	14-Apr-07	162	3	42	28	45	162.3		5529	48.2	42.6
May	workday	Wed	9-May-07	164	3	28	35	41	163.6		5529	47.1	40.2
	weekend	Sat	12-May-07	163	3	20	35	43	162.7		5529	48.5	41.3
Jun	workday	Wed	6-Jun-07	164	3	16	33	26	163.7		5529	50.0	42.7
	weekend	Sat	2-Jun-07	163	3	20	41	58	163.0		5529	48.8	40.3
Jul	workday	Wed	25-Jul-07	161	3	28	27	11	161.0		5529	46.3	41.0
	weekend	Sat	29-Jul-07	164	3	33	36	46	164.0		5529	46.1	39.3
Aug	workday	Wed	22-Aug-07	161	3	25	26	26	161.0		5529	47.0	41.6
	weekend	Sat	18-Aug-07	164	3	33	26	40	163.7		5529	46.0	40.9
Sep	workday	Wed	19-Sep-07	162	3	20	46	54	161.7		5529	48.3	39.2
	weekend	Sat	22-Sep-07	158	3	27	40	51	158.2		5529	45.8	38.3
Oct	workday	Wed	31-Oct-07	162	3	21	22	44	162.5		5529	48.5	43.5
	weekend	Sat	27-Oct-07	160	3	23	34	50	160.4		5529	47.2	34.6
Nov	workday	Tue	6-Nov-07	160	3	28	40	17	159.6		5529	45.9	38.5
	weekend	Sat	3-Nov-07	158	3	18	26	10	158.1		5529	47.8	42.2
Dec	workday	Wed	5-Dec-07	162	3	27	37	10	161.8		5529	46.8	39.7
	weekend	Sat	8-Dec-07	163	3	34	44	13	163.3		5529	45.7	37.9
			Average	161	3	26	33	36	161		5529	47	40

A.7.2. Time and speed data compiled from trip odometer of GPS

Workday Travel Time, 11.00am - 15.30pm, 2007				
	Moving time	Stopped	Moving avg	Overall avg
	hour	minute	km/h	km/h
25-Jan-07	3.52	28.75	44.2	38.9
14-Feb-07	3.52	28.75	44.2	38.9
14-Mar-07	3.72	36.58	43.7	37.5
11-Apr-07	3.48	47.17	45.9	37.5
9-May-07	3.47	35.68	47.1	40.2
6-Jun-07	3.27	33.43	50.0	42.7
25-Jul-07	3.47	27.18	46.3	41.0
22-Aug-07	3.42	26.43	47.0	41.6
19-Sep-07	3.33	46.90	48.3	39.2
31-Oct-07	3.35	22.73	48.5	43.5
6-Nov-07	3.47	40.28	45.9	38.5
5-Dec-07	3.45	37.17	46.8	39.7
Average	3.45	34.26	46.49	39.93

Weekend Travel Time, 11.00am - 15.30pm, 2007				
	Moving time	Stopped	Moving avg	Overall avg
	hour	minute	km/h	km/h
27-Jan-07	3.52	28.75	44.2	38.9
11-Feb-07	3.17	25.87	50.2	44.2
18-Mar-07	3.28	28.67	49.2	42.9
14-Apr-07	3.70	28.75	48.2	42.6
12-May-07	3.33	35.72	48.5	41.3
2-Jun-07	3.33	41.97	48.8	40.3
29-Jul-07	3.55	36.77	46.1	39.3
18-Aug-07	3.55	26.67	46.0	40.9
22-Sep-07	3.45	40.85	45.8	38.3
27-Oct-07	3.38	34.83	47.2	34.6
3-Nov-07	3.30	26.17	47.8	42.2
8-Dec-07	3.57	44.22	45.7	37.9
Average	3.43	33.27	47.31	40.28

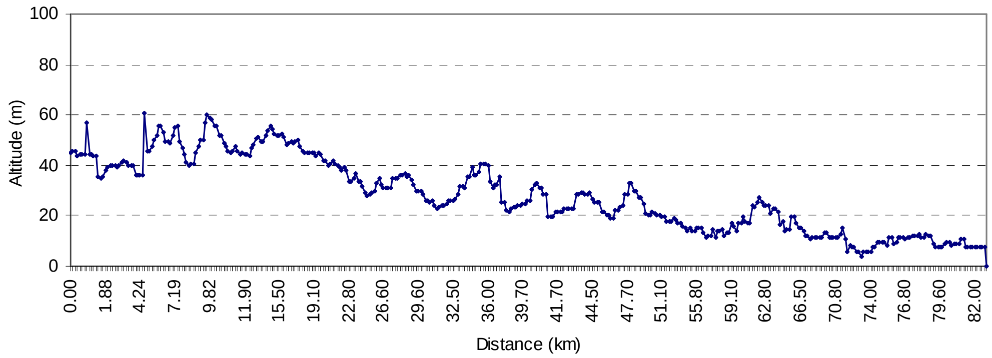
A.7.3. Average travel time and speed by typical day , 11.00am-15.00pm, 2007

Typical	Moving time (hour)	Stopped (minute)	Moving average (km/h)	Overall average (km/h)
Workday	3.45	34.26	46.49	39.93
Weekend	3.43	33.27	47.31	40.28
Average	3.43	33.27	47.31	40.28

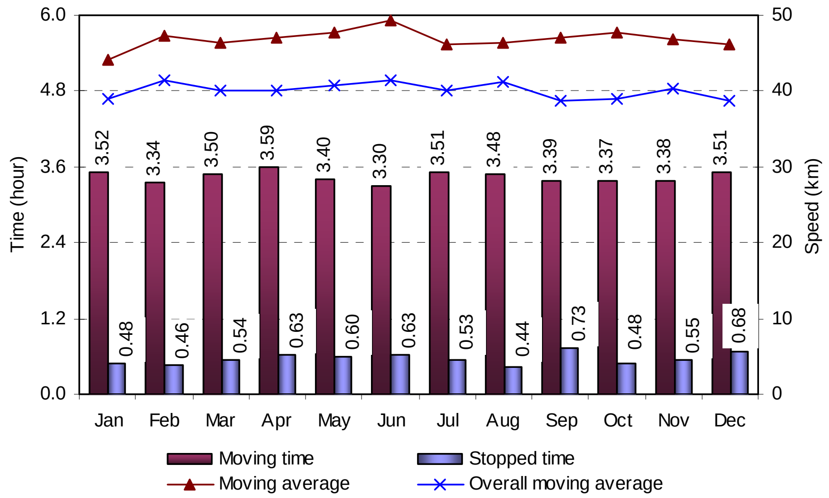
A.7.4. Name of location, stationing, altitude, and terrain.

No	Location name	Location
1	Ipoh	Km. 0.0
2	Taman Maju	Km. 30.2
3	Bota Kanan	Km. 41.5
4	Ayer Tawar	Km. 59.1
5	Sitiawan	Km. 71.0
6	Manjung	Km. 75.3
7	Lumut	Km. 82.6
	Distance (km)	82.6
	Max altitude (m)	60.70
	Min altitude (m)	7.35
	Slope	0.646

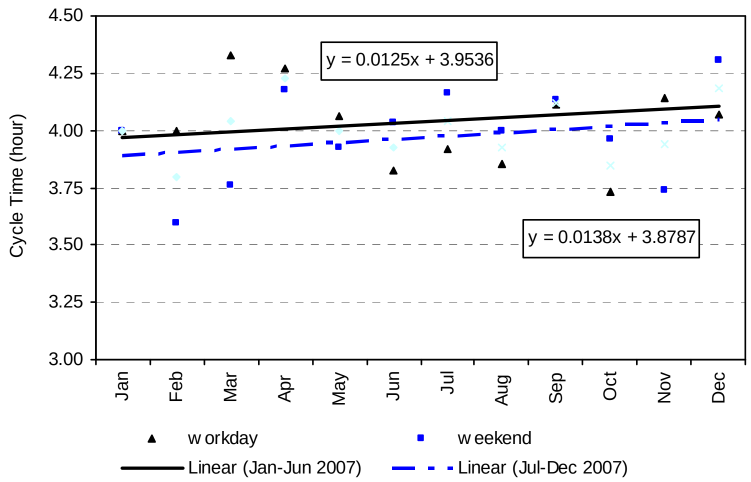
A.7.5. Altitude of point along the bus route (in meter) from mean sea level



A.7.6. Average monthly travel time and speed, 11.00am-15.00pm, 2007



A.7.7. Trend line of cycle time by 1st and 2nd semester, 11.00am-15.00pm, 2007



A.8. Data of Boarding and Alighting of Passengers

Jan
workday
Thursday, Jan 25, 2007

Distance	Ipoh to Lumut		Lumut to Ipoh		Two way	
km	GetOn	GetOff	GetOn	GetOff	GetOn	GetOff
0.0	21	0	0	15	21	15
4.8	1	0	0	0	1	0
11.7	1	0	0	0	1	0
23.8	0	1	0	0	0	1
26.0	0	0	0	1	0	1
27.6	0	0	1	0	1	0
30.0	0	0	0	1	0	1
30.2	1	0	0	0	1	0
31.7	0	0	1	1	1	1
31.8	1	0	0	0	1	0
32.1	0	1	0	0	0	1
32.3	0	1	0	0	0	1
32.9	0	0	6	0	6	0
34.9	0	0	0	4	0	4
35.6	0	0	0	2	0	2
38.4	0	0	0	1	0	1
39.4	0	0	0	4	0	4
41.4	0	0	3	0	3	0
41.5	0	2	9	0	9	2
43.1	7	0	0	2	7	2
45.6	3	0	0	1	3	1
46.3	0	0	1	0	1	0
47.3	0	0	0	1	0	1
48.3	3	0	0	0	3	0
48.5	0	0	1	0	1	0
50.4	1	0	0	0	1	0
52.9	1	0	0	0	1	0
53.4	1	0	0	0	1	0
53.6	1	0	0	0	1	0
54.4	3	0	0	0	3	0
56.1	0	1	0	0	0	1
58.2	0	3	0	0	0	3
58.6	1	1	0	0	1	1
59.1	2	5	1	4	3	9
59.4	2	0	0	0	2	0
60.0	1	0	0	1	1	1
60.3	1	0	0	0	1	0
61.1	1	2	0	0	1	2
63.6	0	0	0	1	0	1
64.4	1	1	1	1	2	2
67.4	3	0	1	0	4	0
68.5	0	0	0	5	0	5
70.9	0	0	9	0	9	0
71.0	0	5	0	0	0	5
71.1	1	0	0	0	1	0
71.5	3	7	0	1	3	8
73.5	0	0	1	0	1	0
74.9	0	0	6	0	6	0
75.3	0	6	0	0	0	6
76.1	1	2	0	0	1	2
78.3	0	1	0	0	0	1
82.6	0	23	5	0	5	23

Jan
weekend
Saturday, Jan 27, 2007

Distance	Ipoh to Lumut		Lumut to Ipoh		Two way	
km	GetOn	GetOff	GetOn	GetOff	GetOn	GetOff
0.0	24	0	0	23	24	23
3.7	1	0	0	0	1	0
27.6	3	0	2	0	5	0
30.0	0	1	0	0	0	1
30.2	0	0	3	2	3	2
30.3	0	0	0	2	0	2
32.5	0	0	0	3	0	3
32.7	5	2	0	0	5	2
34.0	4	2	4	0	8	2
41.2	19	0	0	0	19	0
41.5	8	3	2	4	10	7
43.1	4	2	0	8	4	10
44.7	0	1	0	0	0	1
44.8	0	0	0	1	0	1
45.6	0	0	0	1	0	1
46.4	7	1	0	5	7	6
46.5	0	1	0	0	0	1
47.2	0	4	0	0	0	4
47.7	0	15	0	0	0	15
48.3	0	4	0	0	0	4
49.3	0	2	0	0	0	2
49.9	0	0	0	4	0	4
58.3	6	2	0	0	6	2
58.7	0	0	4	2	4	2
58.8	8	6	0	0	8	6
59.1	5	3	11	0	16	3
59.8	0	0	0	1	0	1
60.7	0	3	0	0	0	3
62.5	0	0	2	0	2	0
64.5	0	3	0	1	0	4
70.5	0	1	0	0	0	1
71.0	0	0	5	0	5	0
71.1	2	5	0	0	2	5
71.5	2	8	0	0	2	8
72.4	0	0	1	0	1	0
72.6	0	1	2	0	2	1
73.5	0	0	0	1	0	1
74.8	0	1	0	0	0	1
75.3	8	6	0	0	8	6
75.5	0	2	0	0	0	2
76.1	3	0	2	0	5	0
77.1	1	2	0	0	1	2
78.0	0	0	0	1	0	1
79.3	0	0	3	0	3	0
82.6	0	29	18	0	18	29

Feb
workday
Wednesday, Feb 14, 2007

Distance	Ipoh to Lumut		Lumut to Ipoh		Two way	
km	GetOn	GetOff	GetOn	GetOff	GetOn	GetOff
0.0	18	0	0	18	18	18
19.6	0	1	0	0	0	1
25.9	0	0	0	1	0	1
30.0	0	0	0	1	0	1
30.4	0	0	0	4	0	4
32.1	0	0	0	1	0	1
32.9	1	0	1	0	2	0
34.0	0	0	1	0	1	0
34.9	0	0	0	3	0	3
35.6	0	0	0	2	0	2
38.2	0	0	0	2	0	2
39.4	0	0	0	1	0	1
41.5	0	2	15	0	15	2
43.1	0	1	0	0	0	1
45.0	0	0	0	1	0	1
46.4	0	0	0	1	0	1
56.1	0	0	0	2	0	2
59.0	0	0	6	1	6	1
59.1	5	4	0	0	5	4
59.2	1	0	0	0	1	0
60.1	1	0	0	0	1	0
60.7	2	0	0	0	2	0
64.3	3	2	0	0	3	2
64.5	0	0	3	4	3	4
67.2	0	0	0	1	0	1
71.0	0	3	8	2	8	5
71.4	0	0	0	7	0	7
71.5	5	5	0	0	5	5
72.0	1	0	0	0	1	0
72.1	0	0	0	2	0	2
72.6	0	0	0	3	0	3
73.3	0	1	0	0	0	1
73.8	0	2	0	0	0	2
74.8	0	3	0	0	0	3
74.9	1	0	0	0	1	0
75.1	0	3	0	0	0	3
75.3	0	0	5	0	5	0
75.5	0	1	0	0	0	1
76.1	0	3	5	0	5	3
76.6	0	0	0	2	0	2
77.1	0	1	0	0	0	1
77.3	0	0	1	0	1	0
78.4	0	1	0	0	0	1
79.3	0	0	0	7	0	7
82.6	0	5	21	0	21	5

Feb
weekend
Sunday, Feb 11, 2007

Distance	Ipoh to Lumut		Lumut to Ipoh		Two way	
km	GetOn	GetOff	GetOn	GetOff	GetOn	GetOff
0.0	25	0	0	50	25	50
7.0	0	0	3	0	3	0
8.7	0	0	0	1	0	1
26.0	0	0	0	1	0	1
27.6	0	1	0	0	0	1
30.0	0	2	2	0	2	2
30.2	2	0	0	4	2	4
31.7	0	3	0	0	0	3
32.6	3	2	0	0	3	2
32.9	3	0	0	0	3	0
34.0	0	2	0	0	0	2
34.4	0	0	4	0	4	0
41.5	1	0	5	0	6	0
46.2	0	0	0	3	0	3
46.3	4	0	0	0	4	0
53.0	0	0	0	1	0	1
58.7	0	0	4	0	4	0
59.1	2	3	2	0	4	3
59.2	8	0	0	0	8	0
59.4	1	0	0	0	1	0
60.5	0	1	0	0	0	1
62.8	0	1	0	0	0	1
67.8	0	2	1	3	1	5
71.0	0	1	5	0	5	1
71.5	7	0	1	2	8	2
72.4	0	1	2	3	2	4
72.6	0	2	0	0	0	2
73.1	0	2	1	0	1	2
73.8	0	0	1	0	1	0
74.9	0	4	0	0	0	4
75.3	0	14	6	0	6	14
76.1	3	6	5	0	8	6
79.6	0	3	0	0	0	3
82.6	0	9	26	0	26	9

Mar
workday
Wednesday, Mar 14, 2007

Distance	Ipoh to Lumut		Lumut to Ipoh		Two way	
km	GetOn	GetOff	GetOn	GetOff	GetOn	GetOff
0.0	30	0	0	26	30	26
4.4	0	0	0	1	0	1
5.0	0	0	0	1	0	1
6.9	0	0	0	2	0	2
8.2	0	0	2	0	2	0
18.2	0	0	0	1	0	1
27.6	0	0	1	1	1	1
27.7	0	1	0	0	0	1
30.0	1	0	3	8	4	8
30.4	0	0	0	3	0	3
32.1	0	1	0	0	0	1
32.3	0	0	1	0	1	0
32.6	0	0	0	6	0	6
32.9	0	0	5	2	5	2
34.0	0	0	1	0	1	0
34.4	0	0	1	0	1	0
34.9	0	0	2	2	2	2
35.6	0	0	0	2	0	2
39.1	0	0	1	1	1	1
39.4	0	0	0	2	0	2
41.2	0	0	1	0	1	0
41.5	8	1	9	9	17	10
43.1	0	0	0	2	0	2
44.5	0	2	1	3	1	5
45.6	0	1	0	0	0	1
47.1	0	0	1	0	1	0
47.2	0	1	0	0	0	1
47.7	1	1	0	1	1	2
48.3	2	0	0	0	2	0
49.3	0	0	0	2	0	2
49.4	3	0	0	0	3	0
49.8	0	0	0	1	0	1
53.0	2	0	0	1	2	1
55.0	0	0	1	0	1	0
55.5	0	0	1	0	1	0
56.0	1	0	0	0	1	0
58.7	0	0	5	0	5	0
59.1	0	5	5	10	5	15
59.2	1	4	0	0	1	4
59.4	0	0	0	3	0	3
60.0	2	0	1	0	3	0
61.2	0	0	1	1	1	1
61.5	0	0	0	1	0	1
62.0	0	1	0	0	0	1
63.1	0	0	0	1	0	1
63.6	1	0	0	0	1	0
64.4	1	0	0	8	1	8
67.4	0	0	0	1	0	1
67.5	0	0	27	6	27	6
69.7	0	0	0	2	0	2
71.0	1	10	13	0	14	10
71.5	5	5	10	6	15	11
72.0	0	0	0	1	0	1
72.6	1	1	0	1	1	2
73.1	0	0	2	0	2	0
73.5	0	2	0	0	0	2
74.4	0	1	1	0	1	1
74.7	1	0	0	0	1	0
75.3	0	7	3	1	3	8
75.5	0	1	0	0	0	1
76.1	1	6	6	1	7	7
78.3	0	0	1	0	1	0
79.3	5	0	3	0	8	0
82.6	0	16	11	0	11	16

Mar
weekend
Sunday, Mar 18, 2007

Distance	Ipoh to Lumut		Lumut to Ipoh		Two way	
km	GetOn	GetOff	GetOn	GetOff	GetOn	GetOff
0.0	43	0	0	55	43	55
4.3	0	0	0	2	0	2
6.3	0	1	0	0	0	1
27.6	0	0	6	0	6	0
27.8	0	2	0	0	0	2
30.0	0	0	3	0	3	0
30.3	0	3	0	1	0	4
30.4	1	0	0	0	1	0
31.7	0	8	0	0	0	8
32.1	0	1	0	0	0	1
32.6	0	5	0	2	0	7
32.9	0	0	2	0	2	0
34.0	1	0	0	0	1	0
35.6	0	1	0	1	0	2
41.5	1	1	0	2	1	3
43.1	2	0	0	0	2	0
44.0	2	0	0	0	2	0
45.0	0	0	0	1	0	1
46.2	0	0	0	1	0	1
47.4	0	0	1	0	1	0
47.7	0	1	0	0	0	1
48.3	2	0	0	0	2	0
50.4	0	0	1	0	1	0
53.0	4	0	1	0	5	0
55.0	2	0	0	0	2	0
57.4	0	0	0	1	0	1
57.7	0	0	2	0	2	0
58.7	0	0	2	0	2	0
58.8	0	5	0	0	0	5
59.1	7	3	3	2	10	5
59.2	0	4	0	0	0	4
60.4	0	5	0	0	0	5
63.6	0	0	0	2	0	2
71.0	0	3	11	0	11	3
71.5	3	8	8	2	11	10
73.1	0	3	0	0	0	3
75.1	0	3	16	0	16	3
76.1	0	6	0	0	0	6
76.4	0	1	0	0	0	1
79.3	0	1	0	2	0	3
82.6	0	3	18	0	18	3

Apr
workday
Wednesday, Apr 11, 2007

Distance	Ipoh to Lumut		Lumut to Ipoh		Two way	
km	GetOn	GetOff	GetOn	GetOff	GetOn	GetOff
0.0	9	0	0	51	9	51
11.4	1	0	0	0	1	0
27.7	0	0	7	0	7	0
30.0	0	0	1	2	1	2
30.2	0	0	0	6	0	6
32.0	0	1	0	0	0	1
32.9	0	0	7	3	7	3
34.0	1	0	0	1	1	1
34.4	0	0	21	0	21	0
34.9	0	0	1	1	1	1
38.2	0	0	2	0	2	0
39.1	0	0	0	2	0	2
41.5	2	0	6	3	8	3
43.1	0	0	0	3	0	3
45.2	0	0	0	1	0	1
46.5	0	0	0	1	0	1
47.7	0	0	2	2	2	2
48.3	0	0	0	2	0	2
50.5	0	0	0	4	0	4
53.0	0	0	0	3	0	3
56.1	0	0	0	2	0	2
58.1	4	0	0	0	4	0
58.7	0	0	14	1	14	1
58.8	0	2	0	0	0	2
59.1	2	0	13	7	15	7
60.0	0	0	2	1	2	1
60.4	0	1	0	1	0	2
60.6	1	0	0	2	1	2
60.8	0	1	0	0	0	1
61.1	1	2	0	0	1	2
61.2	0	0	1	0	1	0
62.8	0	0	0	1	0	1
63.6	0	0	2	0	2	0
64.4	5	0	6	4	11	4
67.4	5	0	0	2	5	2
67.7	0	0	0	2	0	2
67.8	1	0	0	0	1	0
71.0	0	7	6	0	6	7
71.5	9	1	13	0	22	1
72.6	1	0	0	0	1	0
73.1	2	3	0	0	2	3
74.7	0	1	0	0	0	1
75.2	0	7	0	0	0	7
75.2	0	3	2	0	2	3
76.1	1	2	0	0	1	2
76.6	0	1	0	0	0	1
77.3	0	2	0	0	0	2
78.6	0	1	0	0	0	1
79.4	0	1	0	0	0	1
82.6	0	9	2	0	2	9

Apr
weekend
Saturday, Apr 14, 2007

Distance	Ipoh to Lumut		Lumut to Ipoh		Two way	
km	GetOn	GetOff	GetOn	GetOff	GetOn	GetOff
0.0	35	0	0	26	35	26
7.6	0	0	0	1	0	1
9.0	1	0	0	0	1	0
11.5	0	0	0	2	0	2
12.5	1	0	0	0	1	0
27.6	3	0	0	0	3	0
30.2	3	5	0	1	3	6
31.6	0	1	0	0	0	1
32.8	5	0	0	0	5	0
32.9	0	0	4	1	4	1
34.0	2	0	0	0	2	0
34.9	0	0	0	1	0	1
36.6	0	0	1	0	1	0
40.3	0	0	0	1	0	1
41.3	7	0	0	0	7	0
41.5	2	3	3	2	5	5
43.0	0	1	0	0	0	1
43.1	1	0	0	2	1	2
44.5	0	2	0	0	0	2
45.2	0	0	1	0	1	0
45.7	3	0	0	0	3	0
46.4	0	1	0	0	0	1
46.7	0	1	0	0	0	1
47.3	3	0	0	0	3	0
48.2	0	4	0	0	0	4
48.4	1	0	0	0	1	0
50.4	0	0	1	0	1	0
53.0	0	2	0	0	0	2
58.2	2	1	0	0	2	1
58.8	0	6	0	0	0	6
59.1	7	1	1	2	8	3
59.4	0	0	0	1	0	1
60.0	0	2	0	0	0	2
60.4	0	1	0	0	0	1
60.7	0	1	0	0	0	1
60.8	0	0	2	0	2	0
61.1	1	0	0	1	1	1
61.2	1	0	0	0	1	0
67.8	3	0	0	0	3	0
71.0	3	12	1	1	4	13
71.5	14	6	0	3	14	9
72.4	1	0	0	1	1	1
72.6	0	0	2	0	2	0
73.1	0	0	2	1	2	1
73.5	1	2	1	0	2	2
74.7	0	5	4	0	4	5
74.8	0	1	1	0	1	1
75.3	0	9	7	1	7	10
76.1	2	2	2	0	4	2
77.0	0	0	1	0	1	0
77.1	0	4	0	0	0	4
77.3	0	2	1	0	1	2
78.7	0	0	1	0	1	0
82.6	0	27	12	0	12	27

May
workday
Wednesday, May 9, 2007

Distance	Ipoh to Lumut		Lumut to Ipoh		Two way	
km	GetOn	GetOff	GetOn	GetOff	GetOn	GetOff
0.0	27	0	0	9	27	9
11.5	0	0	0	1	0	1
27.6	0	1	1	0	1	1
30.0	2	1	0	0	2	1
30.1	1	1	0	0	1	1
30.2	0	0	2	4	2	4
31.7	0	1	0	1	0	2
32.6	0	2	0	0	0	2
32.9	1	0	4	2	5	2
34.9	0	0	0	2	0	2
35.6	0	0	0	3	0	3
36.6	0	0	0	1	0	1
38.4	0	0	0	1	0	1
39.9	0	0	0	4	0	4
41.5	2	1	13	0	15	1
43.0	0	1	0	0	0	1
43.1	0	0	0	1	0	1
47.4	1	0	0	0	1	0
48.3	0	1	0	0	0	1
53.0	0	2	0	1	0	3
56.2	0	0	0	2	0	2
58.0	0	0	0	1	0	1
59.0	0	0	0	3	0	3
59.1	0	4	0	0	0	4
59.2	1	0	0	0	1	0
59.8	0	0	0	1	0	1
60.4	0	0	4	0	4	0
61.2	0	1	0	0	0	1
62.8	1	0	0	2	1	2
64.5	0	0	0	9	0	9
64.7	1	0	0	0	1	0
67.4	0	1	0	2	0	3
67.8	1	3	1	2	2	5
71.0	0	4	16	0	16	4
71.5	0	0	3	2	3	2
71.7	0	0	0	1	0	1
72.0	1	0	0	0	1	0
73.1	0	1	0	0	0	1
74.2	0	1	0	1	0	2
75.3	0	3	4	0	4	3
75.5	1	5	0	0	1	5
76.1	2	1	2	0	4	1
77.4	0	0	0	1	0	1
79.3	5	0	1	0	6	0
82.6	0	12	6	0	6	12

May
weekend
Saturday, May 12, 2007

Distance	Ipoh to Lumut		Lumut to Ipoh		Two way	
km	GetOn	GetOff	GetOn	GetOff	GetOn	GetOff
0.0	14	0	0	9	14	9
27.6	0	1	0	0	0	1
27.8	0	0	0	1	0	1
30.2	0	0	0	8	0	8
32.3	0	0	9	0	9	0
32.9	4	0	0	0	4	0
34.9	0	0	0	1	0	1
36.6	1	0	0	0	1	0
40.0	1	0	0	0	1	0
41.5	0	0	2	1	2	1
42.1	0	1	0	0	0	1
48.4	0	0	0	1	0	1
52.6	0	0	1	0	1	0
53.0	0	0	0	4	0	4
54.0	0	0	0	1	0	1
58.2	0	0	0	2	0	2
58.7	0	0	3	0	3	0
59.1	2	1	6	0	8	1
59.4	0	0	0	1	0	1
64.4	1	3	0	0	1	3
67.9	1	0	0	0	1	0
71.0	0	3	1	0	1	3
71.5	0	0	0	15	0	15
72.6	2	1	1	0	3	1
75.1	0	3	0	0	0	3
75.3	0	0	4	6	4	6
76.1	1	1	13	0	14	1
76.8	0	1	0	0	0	1
78.5	0	0	1	0	1	0
82.6	0	12	9	0	9	12

Jun
workday
Wednesday, Jun 6, 2007

Distance	Ipoh to Lumut		Lumut to Ipoh		Two way	
km	GetOn	GetOff	GetOn	GetOff	GetOn	GetOff
0.0	16	0	0	24	16	24
1.7	2	0	0	0	2	0
23.1	0	0	0	1	0	1
24.1	0	2	0	0	0	2
30.0	1	1	0	0	1	1
36.2	0	0	2	0	2	0
41.5	0	2	4	0	4	2
46.2	0	0	0	1	0	1
46.7	0	0	0	2	0	2
49.2	0	0	0	1	0	1
58.1	0	0	0	2	0	2
59.1	0	1	1	3	1	4
59.2	1	0	0	0	1	0
59.7	0	0	1	0	1	0
62.8	0	0	0	1	0	1
64.4	4	0	0	0	4	0
64.5	0	0	2	1	2	1
67.7	0	0	0	2	0	2
68.2	0	0	1	0	1	0
70.1	0	0	1	0	1	0
70.8	0	0	1	0	1	0
71.0	0	3	5	0	5	3
71.5	8	2	3	1	11	3
72.5	1	0	0	0	1	0
72.6	0	0	2	0	2	0
73.0	0	1	0	0	0	1
75.2	0	3	8	0	8	3
75.5	1	0	0	0	1	0
76.1	1	4	2	0	3	4
77.3	0	1	0	0	0	1
77.9	0	1	0	0	0	1
82.6	0	14	6	0	6	14

Jun
weekend
Saturday, Jun 2, 2007

Distance	Ipoh to Lumut		Lumut to Ipoh		Two way	
km	GetOn	GetOff	GetOn	GetOff	GetOn	GetOff
0.0	32	0	0	33	32	33
5.1	1	0	0	0	1	0
7.8	8	0	0	0	8	0
8.1	1	0	0	0	1	0
12.5	0	2	1	1	1	3
18.0	0	0	1	0	1	0
19.6	0	1	0	0	0	1
27.6	3	0	4	1	7	1
30.0	1	4	0	0	1	4
30.2	4	0	0	0	4	0
30.3	0	0	0	1	0	1
31.7	1	1	0	0	1	1
32.1	1	0	0	0	1	0
32.3	0	0	4	0	4	0
32.9	14	1	6	1	20	2
35.6	3	0	0	0	3	0
40.0	0	0	0	2	0	2
40.9	0	0	1	0	1	0
41.5	7	4	5	2	12	6
43.1	0	0	2	1	2	1
43.2	0	2	0	0	0	2
43.9	0	0	3	0	3	0
44.7	2	1	0	0	2	1
45.0	1	0	0	0	1	0
45.2	0	2	0	0	0	2
45.6	4	1	0	0	4	1
46.3	0	1	0	0	0	1
48.3	0	2	0	0	0	2
48.5	1	2	0	0	1	2
50.3	0	0	0	1	0	1
53.0	7	2	0	0	7	2
58.6	0	0	1	0	1	0
59.0	0	0	0	2	0	2
59.3	7	19	0	0	7	19
60.3	4	0	0	0	4	0
61.1	0	6	0	0	0	6
61.2	4	0	0	0	4	0
64.4	2	1	0	2	2	3
71.0	0	4	4	0	4	4
71.5	0	22	2	5	2	27
72.3	0	0	0	1	0	1
72.6	0	0	0	1	0	1
73.0	0	0	0	2	0	2
73.1	0	1	0	0	0	1
74.2	0	6	0	0	0	6
74.8	0	0	0	1	0	1
75.3	6	12	0	0	6	12
75.5	1	1	0	0	1	1
76.1	0	0	6	6	6	6
76.6	0	1	0	0	0	1
79.3	0	0	1	0	1	0
82.6	0	16	22	0	22	16

Jul
workday
Wednesday, Jul 25, 2007

Distance	Ipoh to Lumut		Lumut to Ipoh		Two way	
km	GetOn	GetOff	GetOn	GetOff	GetOn	GetOff
0.0	14	0	0	11	14	11
8.1	0	0	0	1	0	1
13.8	0	0	0	2	0	2
24.2	0	0	0	2	0	2
27.6	0	0	2	0	2	0
30.0	0	0	0	3	0	3
30.1	0	1	0	0	0	1
30.4	0	0	0	4	0	4
31.8	1	0	0	2	1	2
32.1	0	0	0	3	0	3
32.9	0	0	5	0	5	0
34.0	0	0	7	0	7	0
34.9	0	0	0	3	0	3
35.6	0	0	0	2	0	2
36.6	0	0	0	6	0	6
38.2	0	0	0	5	0	5
39.1	0	0	0	1	0	1
39.8	0	0	0	2	0	2
40.0	0	0	0	5	0	5
40.3	1	0	0	0	1	0
41.5	1	3	24	2	25	5
43.0	0	3	0	0	0	3
43.1	1	0	1	0	2	0
46.4	0	0	0	1	0	1
47.4	0	0	1	0	1	0
48.4	0	0	0	2	0	2
49.2	0	0	1	0	1	0
53.0	1	0	0	0	1	0
58.8	0	3	0	0	0	3
59.1	0	0	6	5	6	5
60.0	0	0	0	1	0	1
60.8	0	0	0	1	0	1
64.5	0	0	1	8	1	8
67.7	0	0	0	2	0	2
71.0	1	0	15	0	16	0
71.5	8	0	0	1	8	1
72.3	0	2	0	0	0	2
72.9	0	3	0	0	0	3
73.1	0	1	0	0	0	1
74.5	0	0	1	0	1	0
75.2	0	7	0	0	0	7
75.3	0	0	7	0	7	0
76.1	1	1	0	0	1	1
77.3	0	1	0	0	0	1
82.6	0	4	4	0	4	4

Jul
weekend
Saturday, Jul 29, 2007

Distance	Ipoh to Lumut		Lumut to Ipoh		Two way	
km	GetOn	GetOff	GetOn	GetOff	GetOn	GetOff
0.0	12	0	0	27	12	27
4.5	0	0	0	1	0	1
11.5	0	0	0	1	0	1
30.1	0	0	0	2	0	2
31.7	1	0	0	2	1	2
32.2	0	0	1	1	1	1
32.6	0	1	0	1	0	2
32.9	0	0	1	0	1	0
34.7	1	0	0	0	1	0
34.9	0	0	2	0	2	0
35.5	0	0	2	1	2	1
39.9	0	0	0	5	0	5
40.8	0	0	0	2	0	2
41.5	1	3	2	4	3	7
44.5	0	0	0	3	0	3
45.6	0	0	0	1	0	1
46.3	9	0	0	0	9	0
46.4	0	0	1	0	1	0
46.5	1	0	0	0	1	0
47.1	0	0	1	0	1	0
47.7	0	0	0	1	0	1
49.2	0	0	1	0	1	0
49.9	0	0	0	2	0	2
53.0	0	0	1	5	1	5
57.8	0	1	0	0	0	1
58.6	0	1	0	0	0	1
58.7	0	0	14	0	14	0
59.1	1	1	7	3	8	4
59.8	0	0	0	3	0	3
60.4	1	0	0	0	1	0
60.8	0	0	1	0	1	0
62.8	0	0	1	0	1	0
63.3	0	0	2	0	2	0
64.5	1	0	1	0	2	0
71.0	1	0	11	0	12	0
71.5	3	2	4	4	7	6
71.7	0	0	0	1	0	1
73.1	0	1	0	0	0	1
74.6	0	0	1	0	1	0
75.2	0	0	9	2	9	2
75.3	0	5	0	0	0	5
76.1	3	2	1	0	4	2
77.1	0	3	0	0	0	3
79.4	0	3	0	0	0	3
82.6	0	12	8	0	8	12

Aug
workday
Wednesday, Aug 22, 2007

Distance	Ipoh to Lumut		Lumut to Ipoh		Two way	
km	GetOn	GetOff	GetOn	GetOff	GetOn	GetOff
0.0	9	0	0	9	9	9
13.5	0	0	1	0	1	0
14.4	0	0	0	1	0	1
18.0	0	0	0	1	0	1
30.2	0	0	0	1	0	1
32.2	0	0	0	1	0	1
36.6	0	0	0	4	0	4
39.1	0	0	0	2	0	2
41.5	1	1	5	3	6	4
43.0	0	2	0	0	0	2
44.8	0	0	2	0	2	0
47.1	0	0	1	0	1	0
48.4	0	0	0	3	0	3
48.9	0	0	1	0	1	0
52.6	0	0	0	2	0	2
53.6	0	0	0	2	0	2
56.9	0	1	0	0	0	1
58.2	0	0	2	1	2	1
58.7	0	0	5	0	5	0
59.1	0	0	2	1	2	1
59.2	0	1	0	0	0	1
64.4	3	0	0	0	3	0
70.8	0	2	0	0	0	2
71.0	0	1	4	0	4	1
71.5	0	1	0	0	0	1
72.6	1	0	0	1	1	1
75.3	0	0	2	0	2	0
76.1	0	0	2	0	2	0
80.7	0	1	0	0	0	1
82.6	0	4	5	0	5	4

Aug
weekend
Saturday, Aug 18, 2007

Distance	Ipoh to Lumut		Lumut to Ipoh		Two way	
km	GetOn	GetOff	GetOn	GetOff	GetOn	GetOff
0.0	6	0	0	19	6	19
7.6	0	0	0	1	0	1
11.4	1	0	0	2	1	2
30.0	0	0	1	1	1	1
30.1	1	0	0	0	1	0
31.7	2	0	0	0	2	0
32.9	3	0	7	0	10	0
34.9	5	0	0	0	5	0
35.6	1	0	0	0	1	0
36.2	0	0	2	0	2	0
38.4	0	0	0	2	0	2
40.0	0	0	0	1	0	1
41.5	15	3	1	2	16	5
43.1	3	4	0	1	3	5
45.6	0	2	0	0	0	2
45.8	0	0	2	0	2	0
47.6	0	0	0	1	0	1
47.7	0	2	0	0	0	2
50.5	0	0	0	4	0	4
53.0	0	0	0	1	0	1
53.9	0	0	0	4	0	4
56.0	0	0	1	2	1	2
56.1	4	0	0	0	4	0
58.7	0	0	6	0	6	0
58.8	0	4	0	0	0	4
59.1	0	7	11	0	11	7
59.2	0	2	0	0	0	2
69.1	0	0	0	1	0	1
71.0	0	2	3	0	3	2
71.5	0	3	2	2	2	5
72.0	2	1	0	0	2	1
74.2	0	2	0	0	0	2
74.7	0	1	0	0	0	1
74.9	0	0	0	1	0	1
75.3	0	0	3	0	3	0
75.8	0	0	0	1	0	1
76.3	0	4	0	0	0	4
79.3	0	0	3	0	3	0
82.6	0	6	4	0	4	6

Sep
workday
Wednesday, Sep 19, 2007

Distance	Ipoh to Lumut		Lumut to Ipoh		Two way	
km	GetOn	GetOff	GetOn	GetOff	GetOn	GetOff
0.0	25	0	0	15	25	15
10.9	0	0	1	0	1	0
23.6	2	0	0	0	2	0
23.7	0	0	0	1	0	1
30.1	4	2	0	0	4	2
31.8	3	0	0	0	3	0
32.9	3	0	0	0	3	0
34.9	1	1	0	1	1	2
35.6	1	0	0	0	1	0
36.1	0	2	0	0	0	2
38.4	0	0	0	1	0	1
41.5	5	1	1	1	6	2
43.1	4	1	0	1	4	2
44.6	1	0	0	0	1	0
44.8	2	0	0	0	2	0
45.4	1	0	0	0	1	0
45.6	0	0	0	1	0	1
47.8	0	1	0	0	0	1
50.4	1	0	0	0	1	0
50.7	0	0	1	1	1	1
51.8	3	6	0	0	3	6
53.0	0	0	0	1	0	1
54.0	2	0	0	0	2	0
56.9	1	0	0	0	1	0
57.2	1	0	0	0	1	0
57.6	0	0	0	1	0	1
58.1	1	0	0	0	1	0
58.4	0	1	0	0	0	1
58.7	0	3	0	0	0	3
58.8	0	10	0	0	0	10
59.1	3	1	8	4	11	5
60.1	0	2	0	0	0	2
60.6	0	1	0	0	0	1
61.1	0	0	2	0	2	0
64.7	0	1	0	0	0	1
71.0	1	6	5	0	6	6
71.4	0	10	3	0	3	10
75.1	0	4	0	0	0	4
76.1	3	0	0	2	3	2
79.3	0	2	0	0	0	2
82.6	0	13	9	0	9	13

Sep
weekend
Saturday, Sep 22, 2007

Distance	Ipoh to Lumut		Lumut to Ipoh		Two way	
km	GetOn	GetOff	GetOn	GetOff	GetOn	GetOff
0.0	35	0	0	9	35	9
1.9	0	0	0	1	0	1
2.3	0	0	0	2	0	2
3.3	0	0	0	1	0	1
5.1	0	0	0	1	0	1
27.6	0	1	0	0	0	1
30.2	0	2	0	0	0	2
31.6	0	0	0	2	0	2
32.6	4	0	0	0	4	0
38.1	0	0	0	2	0	2
38.4	0	0	0	6	0	6
41.5	4	0	1	2	5	2
43.0	0	2	0	0	0	2
43.1	0	0	0	4	0	4
43.2	4	0	0	0	4	0
46.2	0	0	0	5	0	5
53.0	0	0	0	2	0	2
56.1	0	1	0	2	0	3
58.0	0	1	0	0	0	1
58.2	0	1	0	0	0	1
58.7	0	0	13	3	13	3
59.1	4	12	3	0	7	12
59.5	0	0	0	1	0	1
60.8	0	0	4	0	4	0
70.5	0	4	0	0	0	4
71.0	0	4	8	0	8	4
71.5	16	3	0	0	16	3
73.0	0	6	0	0	0	6
73.1	0	2	0	0	0	2
73.5	0	3	0	0	0	3
75.1	3	7	0	0	3	7
75.5	0	1	0	0	0	1
76.1	4	4	0	0	4	4
79.3	0	1	0	0	0	1
82.6	0	19	14	0	14	19

Oct
workday
Wednesday, Oct 31, 2007

Distance	Ipoh to Lumut		Lumut to Ipoh		Two way	
km	GetOn	GetOff	GetOn	GetOff	GetOn	GetOff
0.0	20	0	0	17	20	17
2.3	1	0	0	0	1	0
19.7	0	0	1	1	1	1
24.9	1	0	0	0	1	0
27.7	0	0	0	1	0	1
30.2	0	0	2	1	2	1
30.3	1	0	0	0	1	0
32.6	1	2	0	0	1	2
32.9	2	0	0	0	2	0
40.0	0	0	0	1	0	1
41.5	3	1	6	0	9	1
43.1	0	0	0	2	0	2
44.8	1	0	0	0	1	0
46.5	1	0	0	0	1	0
48.9	0	0	0	1	0	1
53.0	0	0	1	1	1	1
57.2	1	0	0	0	1	0
58.6	1	0	0	0	1	0
58.7	0	0	3	2	3	2
59.1	4	4	1	3	5	7
60.1	0	0	1	0	1	0
60.5	0	2	2	0	2	2
62.8	0	1	0	0	0	1
71.0	0	3	2	0	2	3
71.5	8	3	1	0	9	3
72.0	1	1	0	0	1	1
72.4	0	0	0	1	0	1
74.2	0	1	0	0	0	1
75.3	0	4	0	0	0	4
76.1	0	1	0	0	0	1
82.6	0	23	11	0	11	23

Oct
weekend
Saturday, Oct 27, 2007

Distance	Ipoh to Lumut		Lumut to Ipoh		Two way	
km	GetOn	GetOff	GetOn	GetOff	GetOn	GetOff
0.0	25	0	0	37	25	37
4.2	0	0	0	1	0	1
27.6	0	0	0	1	0	1
30.0	0	1	0	0	0	1
30.2	0	0	0	2	0	2
32.6	0	0	0	1	0	1
32.9	4	0	0	0	4	0
35.6	0	0	0	3	0	3
41.5	6	1	2	1	8	2
43.0	0	2	0	0	0	2
44.5	0	1	0	0	0	1
46.2	0	0	2	0	2	0
46.3	2	0	0	0	2	0
47.4	0	0	2	0	2	0
48.3	0	0	0	1	0	1
53.0	1	0	0	0	1	0
56.0	4	0	0	4	4	4
59.1	3	2	5	1	8	3
59.4	0	1	0	0	0	1
59.5	0	0	2	0	2	0
59.8	0	2	0	0	0	2
60.1	0	1	0	0	0	1
60.6	1	0	0	0	1	0
63.6	0	2	0	0	0	2
71.0	0	0	15	0	15	0
71.1	0	2	0	0	0	2
71.6	0	5	0	0	0	5
72.4	0	1	0	0	0	1
73.1	1	0	0	0	1	0
73.5	0	0	0	2	0	2
74.7	0	1	0	0	0	1
75.3	0	7	4	1	4	8
77.1	0	0	2	2	2	2
79.3	0	0	4	0	4	0
82.6	0	18	19	0	19	18

Nov
workday
Tuesday, Nov 6, 2007

Distance	Ipoh to Lumut		Lumut to Ipoh		Two way	
km	GetOn	GetOff	GetOn	GetOff	GetOn	GetOff
0.0	27	0	0	31	27	31
19.3	2	0	0	0	2	0
23.7	0	0	0	1	0	1
25.8	0	0	0	1	0	1
27.6	2	0	0	0	2	0
30.0	0	1	0	0	0	1
30.2	0	0	0	10	0	10
31.9	1	0	0	2	1	2
32.3	0	0	1	0	1	0
32.9	12	0	17	2	29	2
34.9	0	0	0	9	0	9
35.6	0	0	0	4	0	4
36.5	0	0	0	2	0	2
39.4	0	0	0	2	0	2
40.0	0	0	1	0	1	0
40.3	0	0	0	1	0	1
41.5	6	0	21	1	27	1
43.1	1	1	0	0	1	1
44.5	1	0	0	0	1	0
44.8	0	0	0	1	0	1
47.2	0	1	0	0	0	1
47.4	0	0	2	0	2	0
53.0	2	2	0	3	2	5
57.2	1	0	0	0	1	0
57.9	1	0	0	0	1	0
58.7	0	0	2	0	2	0
59.1	3	0	1	6	4	6
59.3	0	2	0	0	0	2
59.9	0	2	0	0	0	2
60.3	1	2	0	0	1	2
60.6	1	1	0	0	1	1
60.8	0	0	6	0	6	0
61.1	0	1	0	0	0	1
67.4	0	2	0	0	0	2
67.7	0	0	0	1	0	1
71.0	1	4	5	0	6	4
71.5	0	7	0	5	0	12
72.0	0	1	0	0	0	1
73.1	0	1	0	0	0	1
75.3	8	13	0	0	8	13
75.5	2	0	0	0	2	0
76.1	0	1	7	1	7	2
79.1	0	0	0	2	0	2
81.4	0	2	0	0	0	2
82.6	0	28	22	0	22	28

Nov
weekend
Saturday, Nov 3, 2007

Distance	Ipoh to Lumut		Lumut to Ipoh		Two way	
km	GetOn	GetOff	GetOn	GetOff	GetOn	GetOff
0.0	23	0	0	30	23	30
1.6	1	0	0	0	1	0
24.0	0	1	0	0	0	1
27.6	1	0	7	1	8	1
30.0	0	1	0	0	0	1
31.7	3	0	0	0	3	0
32.1	0	0	1	0	1	0
34.0	0	1	0	0	0	1
41.5	0	2	2	1	2	3
43.1	0	0	0	1	0	1
44.5	0	0	1	0	1	0
44.9	0	0	0	2	0	2
46.3	2	0	0	0	2	0
46.5	2	0	0	0	2	0
47.3	0	0	0	4	0	4
47.7	1	0	0	0	1	0
48.3	4	0	0	0	4	0
49.0	2	0	0	0	2	0
53.5	0	0	0	1	0	1
53.9	2	0	0	0	2	0
55.7	0	2	0	0	0	2
56.0	2	0	0	0	2	0
58.7	0	0	5	0	5	0
59.1	10	8	4	2	14	10
59.2	0	0	0	2	0	2
60.0	0	0	2	0	2	0
60.1	2	1	0	0	2	1
60.4	0	0	0	1	0	1
60.6	0	2	0	0	0	2
60.7	2	0	0	0	2	0
63.6	4	0	0	0	4	0
64.4	2	0	0	2	2	2
67.9	1	1	0	0	1	1
71.0	1	5	7	0	8	5
71.5	0	12	5	11	5	23
73.1	0	3	0	0	0	3
74.1	0	0	3	0	3	0
74.2	1	2	0	0	1	2
74.8	0	1	0	0	0	1
75.3	2	4	9	0	11	4
75.5	0	0	0	2	0	2
76.1	2	0	4	2	6	2
76.6	1	0	0	0	1	0
79.3	1	0	0	0	1	0
82.6	0	26	12	0	12	26

Dec
workday
Wednesday, Dec 5, 2007

Distance	Ipoh to Lumut		Lumut to Ipoh		Two way	
km	GetOn	GetOff	GetOn	GetOff	GetOn	GetOff
0.0	32	0	0	39	32	39
5.5	1	0	0	0	1	0
13.9	0	0	0	1	0	1
24.4	0	0	0	2	0	2
26.0	0	0	0	1	0	1
27.6	0	3	0	0	0	3
30.0	0	2	0	0	0	2
30.1	0	0	0	18	0	18
31.7	1	1	0	0	1	1
32.3	0	0	0	1	0	1
32.9	0	0	22	0	22	0
34.0	1	0	0	0	1	0
34.9	0	0	4	2	4	2
35.6	0	0	0	2	0	2
39.3	0	0	1	0	1	0
41.5	0	1	5	1	5	2
43.0	0	1	0	0	0	1
43.1	1	0	0	5	1	5
44.8	2	0	0	0	2	0
45.6	0	0	0	5	0	5
46.5	0	1	0	1	0	2
47.7	0	0	0	1	0	1
48.4	0	0	0	1	0	1
49.2	0	0	0	1	0	1
49.9	0	0	0	2	0	2
50.1	0	0	1	1	1	1
50.4	0	0	0	3	0	3
53.0	0	0	2	4	2	4
53.8	0	0	0	5	0	5
54.9	0	0	2	0	2	0
55.3	0	0	0	1	0	1
57.2	0	1	0	0	0	1
58.7	0	0	2	0	2	0
58.8	0	3	0	0	0	3
59.1	3	0	19	9	22	9
59.9	0	0	4	0	4	0
60.8	0	0	0	1	0	1
64.4	0	1	0	0	0	1
70.9	3	0	0	0	3	0
71.0	0	1	11	1	11	2
71.4	0	4	0	0	0	4
71.5	0	0	0	5	0	5
72.4	0	1	0	1	0	2
73.5	0	0	1	0	1	0
74.5	0	0	2	0	2	0
75.3	3	8	6	1	9	9
75.5	1	0	0	0	1	0
76.1	3	2	0	0	3	2
82.6	0	21	33	0	33	21

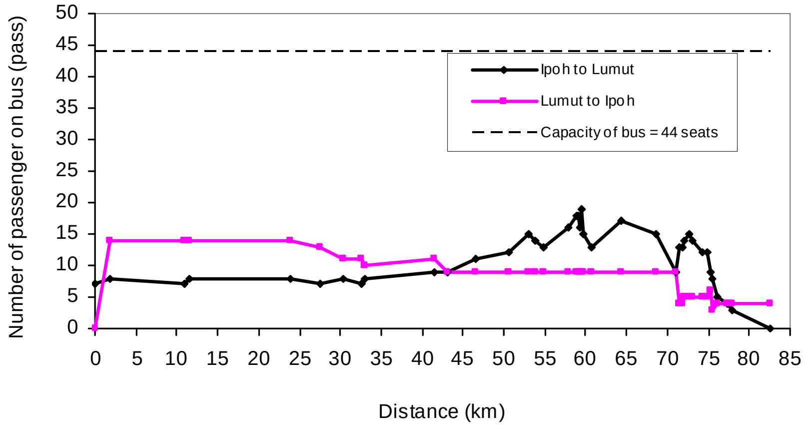
Dec
weekend
Saturday, Dec 8, 2007

Distance	Ipoh to Lumut		Lumut to Ipoh		Two way	
km	GetOn	GetOff	GetOn	GetOff	GetOn	GetOff
0.0	30	0	0	43	30	43
19.1	0	0	0	2	0	2
19.7	0	0	1	0	1	0
24.4	0	0	0	1	0	1
27.6	1	0	4	1	5	1
29.9	0	0	1	0	1	0
30.1	0	0	0	3	0	3
32.1	1	0	0	0	1	0
32.6	3	0	0	0	3	0
32.9	0	0	3	0	3	0
34.0	2	1	3	0	5	1
35.6	0	1	0	0	0	1
36.0	0	0	4	0	4	0
41.5	5	2	3	1	8	3
43.1	4	1	1	0	5	1
43.7	1	0	0	0	1	0
44.4	1	0	0	0	1	0
44.5	0	0	2	0	2	0
44.8	0	0	0	2	0	2
45.4	0	0	0	1	0	1
45.8	0	0	0	1	0	1
46.3	0	2	0	2	0	4
48.9	0	1	0	0	0	1
49.1	1	0	0	0	1	0
50.9	0	0	0	3	0	3
52.8	0	0	0	1	0	1
58.2	0	0	0	3	0	3
58.7	0	0	0	2	0	2
59.0	0	8	0	0	0	8
59.0	0	1	0	6	0	7
59.3	0	0	0	8	0	8
60.8	0	1	0	0	0	1
61.2	0	0	0	5	0	5
62.8	0	0	0	1	0	1
64.3	0	0	0	2	0	2
67.9	0	2	0	0	0	2
71.0	0	0	8	1	8	1
71.4	0	1	20	9	20	10
71.9	0	0	0	1	0	1
72.3	0	0	2	0	2	0
73.5	0	0	5	0	5	0
74.2	0	0	0	1	0	1
74.7	0	0	1	0	1	0
75.3	0	4	15	4	15	8
76.1	0	0	1	1	1	1
76.8	0	4	0	0	0	4
78.3	0	0	1	0	1	0
78.7	0	1	0	0	0	1
82.6	0	19	30	0	30	19

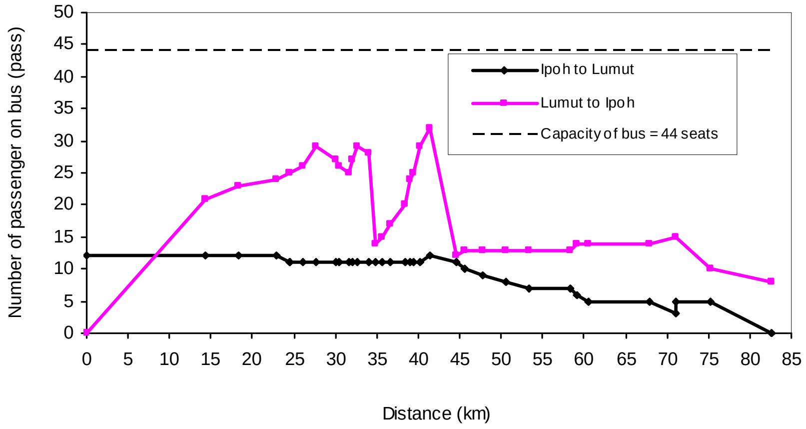
A.9. Passengers Loading Profile

A.9.1. Boarding and Alighting of Passengers during Full One Day

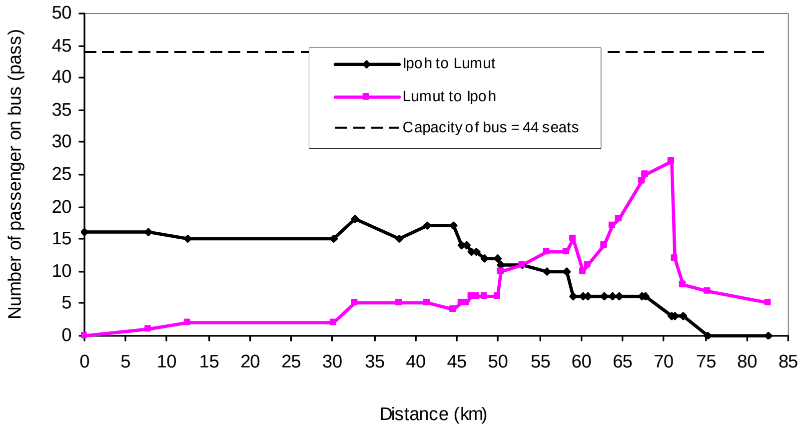
A.9.1.1. Roundtrip 1 (7:04-10:42)



A.9.1.2. Roundtrip 2 (11:05-15:04)

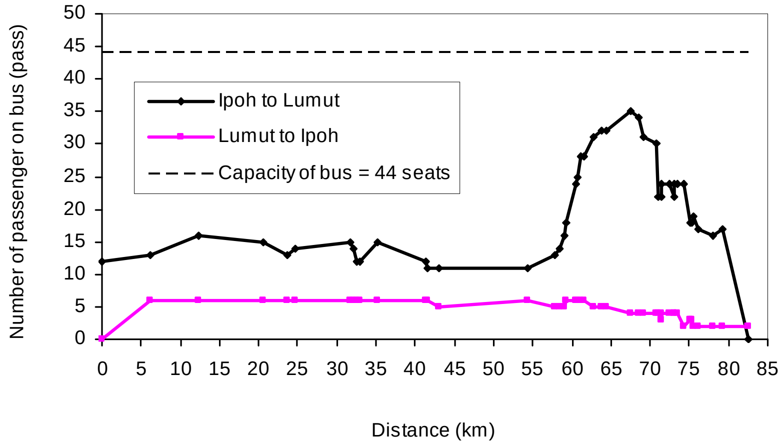


A.9.1.3. Roundtrip 3 (16:05-20:10)

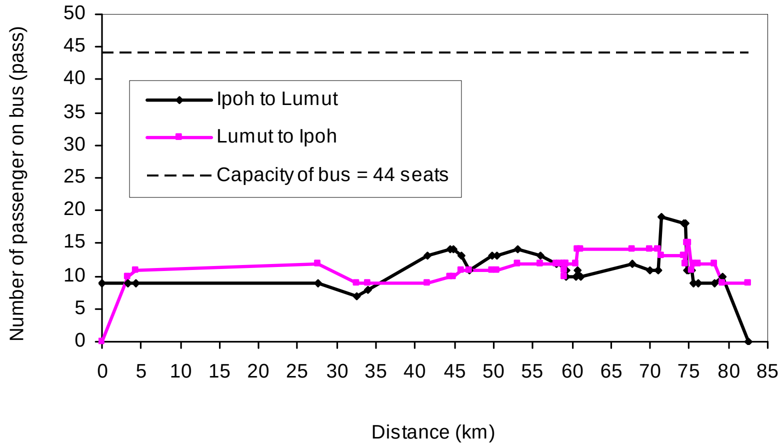


A.9.2. Boarding and Alighting of Passengers during One Week

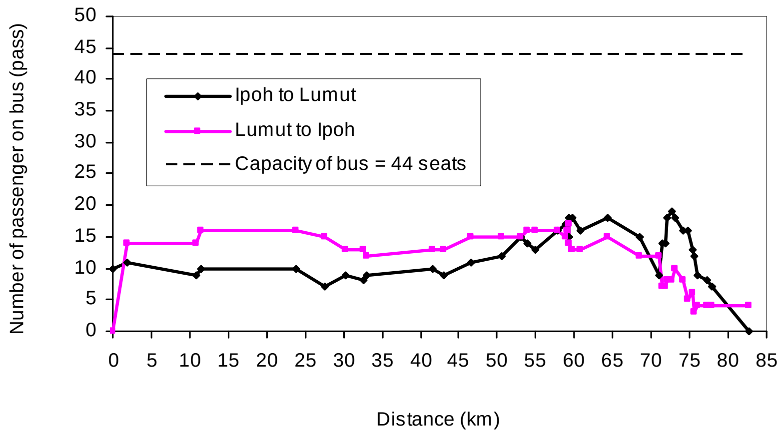
A.9.2.1. Monday (11:00-15:00)



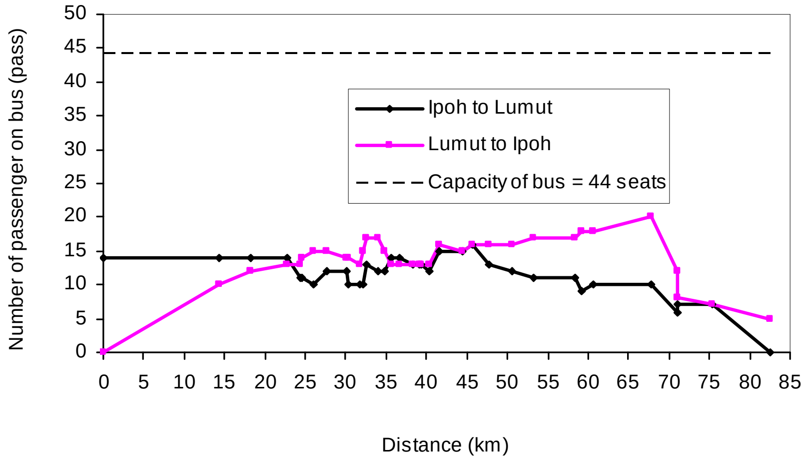
A.9.2.2. Tuesday (11:00-15:00)



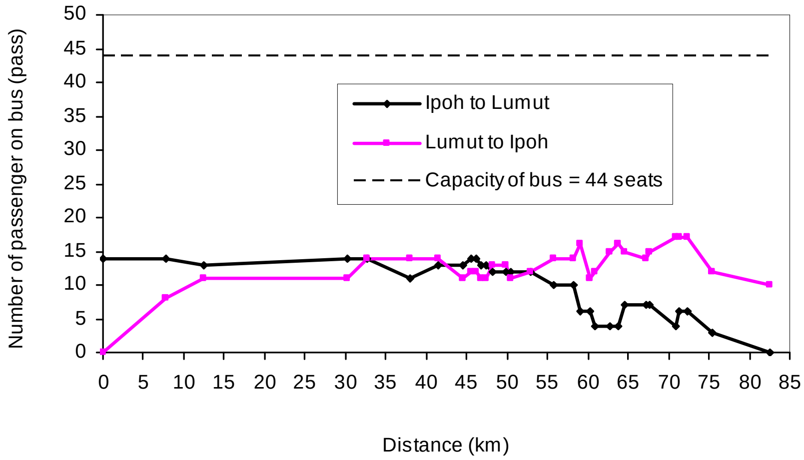
A.9.2.3. Wednesday (11:00-15:00)



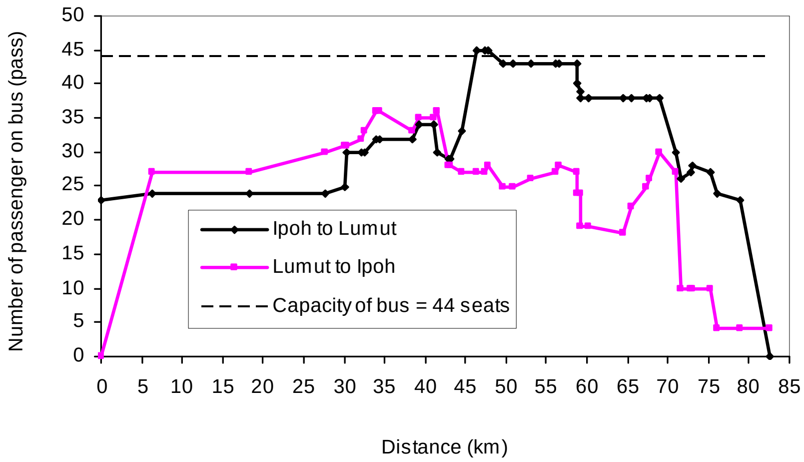
A.9.2.4. Thursday (11:00-15:00)



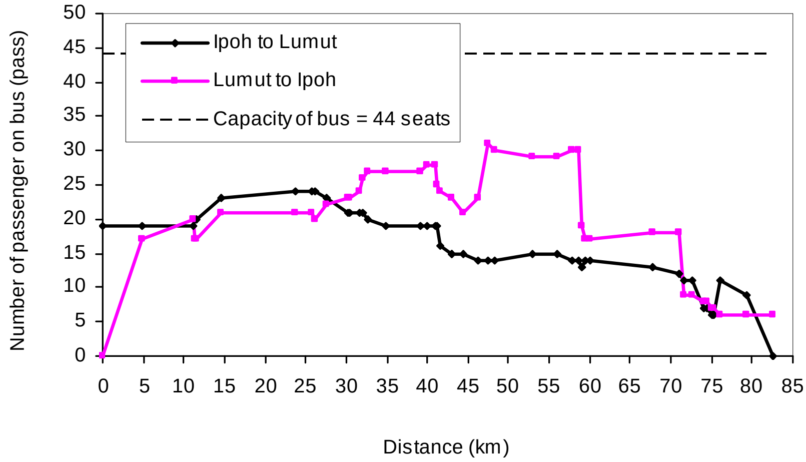
A.9.2.5. Friday (11:00-15:00)



A.9.2.6. Saturday (11:00-15:00)



A.9.2.7. Sunday (11:00-15:00)

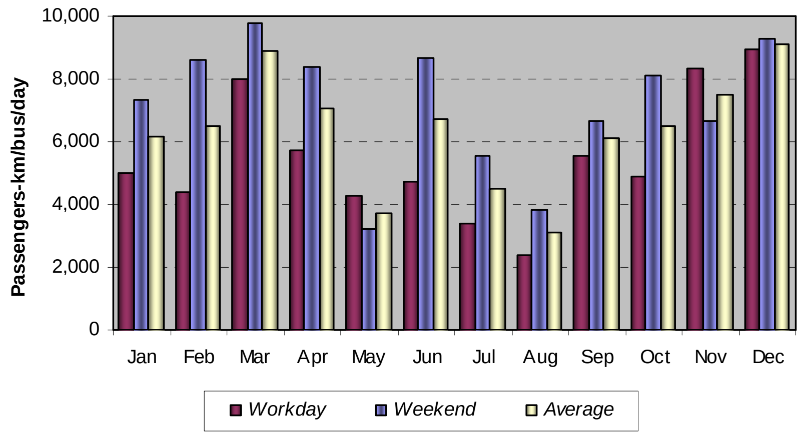


A.10. Trip Productivity

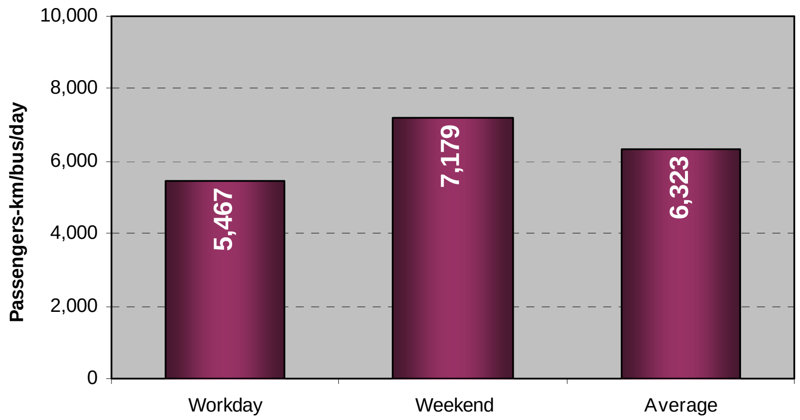
A.10.1. Passengers-Kilometer per Bus per Day (two ways) in 2007

Month	Workday	Weekend	Average
Jan	5,012	7,353	6,183
Feb	4,395	8,626	6,510
Mar	8,023	9,757	8,890
Apr	5,719	8,405	7,062
May	4,275	3,225	3,750
Jun	4,747	8,670	6,708
Jul	3,392	5,574	4,483
Aug	2,362	3,821	3,091
Sep	5,535	6,660	6,097
Oct	4,886	8,096	6,491
Nov	8,334	6,668	7,501
Dec	8,922	9,301	9,112
Average	5,467	7,179	6,323

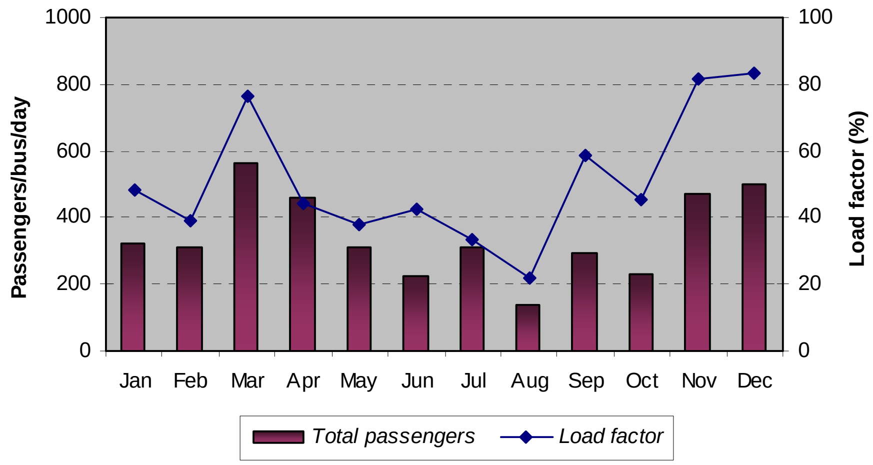
A.10.1.1. Monthly passenger-km per bus per day



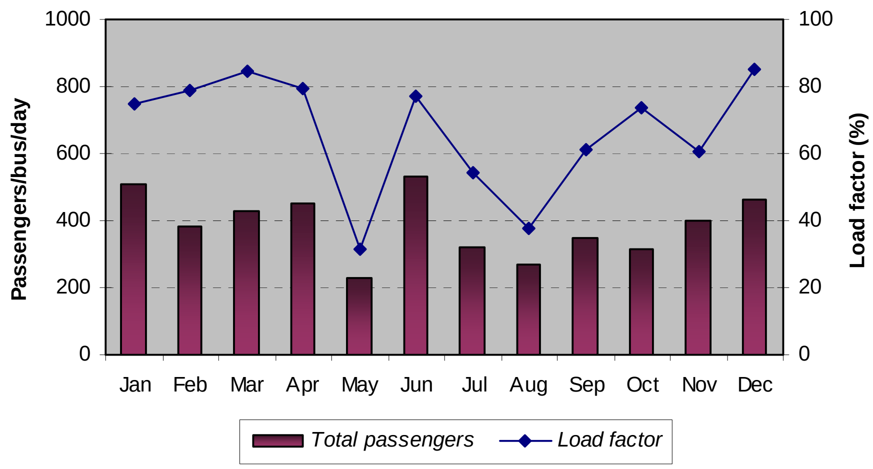
A.10.1.2. Passenger-km per bus per day by typical day



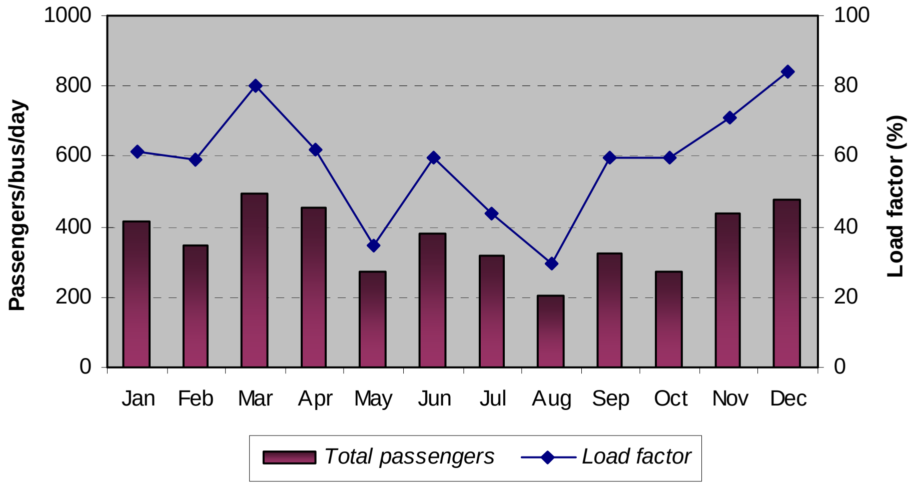
A.10.2. Total passengers and load factor (workday) in 2007



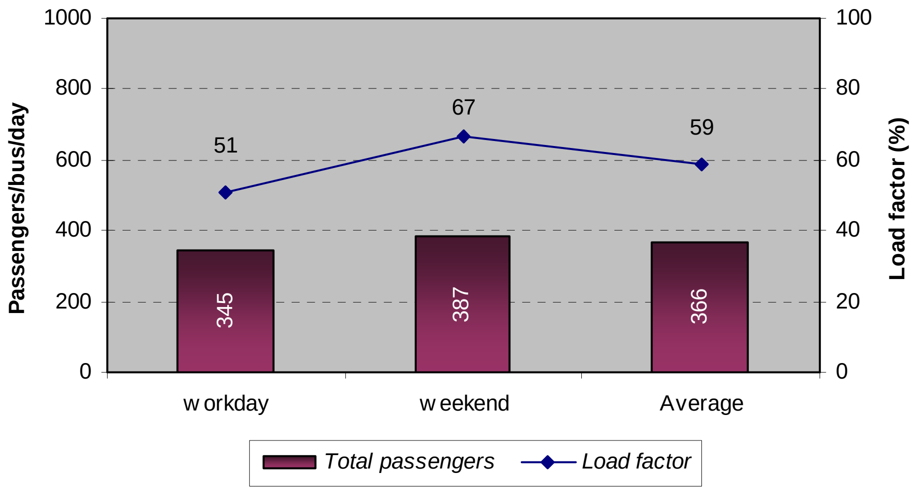
A.10.3. Total passengers and load factor (weekday) in 2007



A.10.4. Total passengers and load factor (average) in 2007



A.10.5. Total passengers and load factor (workday and weekend) in 2007



APPENDIX B:

Characteristics of Bus Fleets

B.1 Kilometer traveled of Bus Operation (Jumlah Bilangan Perbatuan Operasi Bagi Setiap Bas)

Bil	No. Kenderaan	Laluan	KM	Trip/hari	2004 km/tahun	2005 km/tahun	2006 km/tahun	Tahun diperbuat	Tarikh pendaftaran bas	Harga pembelian
1	**ACT3800**	Ipoh-Grik	154	2	73920	88704	103488			
2	**AEJ9200**	Ipoh-Grik	154	2	73920	88704	103488			
3	**AEN8700**	Ipoh-Grik	154	2	73920	88704	103488			
4	**AEN8600**	Ipoh-Grik	154	2	73920	88704	103488			
5	**AES9700**	Ipoh-Grik	154	4	147840	177408	206976			
6	**AEV6600**	Ipoh-Betong	203	2	97440	116928	136416			
7	**ACX600**	Ipoh-Lumut	86	6	123840	148608	173376	1995	12/23/1995	RM122,000
8	**ADF8300**	Ipoh-Lumut	86	6	123840	148608	173376	1996	1/21/1997	RM193,000
9	**AEE5600**	Ipoh-Lumut	86	6	123840	148608	173376	1997	12/14/2000	RM188,000
10	**AEX7800**	Ipoh-Lumut	86	6	123840	148608	173376	2001	12/4/2003	RM205,000
11	**ABR8500**	Ipoh-Lumut	86	6	123840	148608	173376	1990	4/17/1990	RM145,000
12	**ABV1800**	Ipoh-Lumut	86	6	123840	148608	173376	1990	1/28/1991	RM142,000
13	**ACA1100**	Ipoh-Lumut	86	6	123840	148608	173376	1991	12/17/1991	RM167,000
14	**ACL2100**	Ipoh-Lumut	86	6	123840	148608	173376	1993	1/17/1994	RM158,000
15	**ACP3100**	Ipoh-Lumut	86	6	123840	148608	173376	1994	8/19/1994	RM105,000
16	**DAS8300**	Ipoh-Kajang	227	2	108960	130752	152544			
17	**AEX1895**	Ipoh-S Alam	230	2	110400	132480	154560			
18	**AEX1903**	Ipoh-S Alam	230	2	110400	132480	154560			
19	**AFM2500**	Ipoh-S Alam	230	2	110400	132480	154560			
20	**AFM2600**	Ipoh-S Alam	230	2	110400	132480	154560			
21	**DAS8200**	Ipoh-S Alam	230	2	110400	132480	154560			
22	**AFV7700**	Ipoh-S Alam	230	2	110400	132480	154560			

B.2 Departure time of bus from both bus stations

No.	From Ipoh	Days	From Lumut
1	7:00 AM	Monday to Thursday	6:20 AM
2	7:30 AM		7:00 AM
3	8:00 AM		7:30 AM
4	8:30 AM		8:50 AM
5	9:00 AM		9:20 AM
6	9:30 AM		9:50 AM
7	10:00 AM		10:20 AM
8	11:00 AM		10:50 AM
9	12:00 PM		11:20 AM
10	1:00 PM		12:50 PM
11	1:30 PM		1:50 PM
12	2:00 PM		2:50 PM
13	2:30 PM		1:50 PM
14	3:00 PM		2:50 PM
15	4:00 PM		3:20 PM
16	5:00 PM		3:50 PM
17	5:30 PM		4:40 PM
18	6:00 PM		5:50 PM
19	7:00 PM		6:45 PM
20	7:30 PM	(Friday/Saturday/Sunday)	7:50 PM

B.3 Bus operation schedule (time of departure)

During 16-22 July 2007

Bus	From Ipoh				No of vehicle	Driver/crew	From Lumut
	Mon-Tue-Wed-Thu			Fri-Sat-Sun			
1	7:00 AM	11:00 AM	4:00 PM		ABR 8500	Sara/Ibrahim	
2	7:30 AM	12:00 PM	5:00 PM		ADF 8300	Sham/Jariah	
3	8:00 AM	1:00 PM	5:30 PM		AEE 5600	Anen/Sukar	7:50 PM *)
4	9:00 AM	2:00 PM			ACA 1100	Ravi/Dahalan	
5	10:00 AM	3:00 PM		7:30 PM	ABV 1800	Alex/Badio	7:30 AM
6	8:30 AM	1:30 PM	6:00 PM		ACX 600	Saari/Rahman	6:20 AM
7	9:30 AM	2:30 PM	7:00 PM		AEX 7800	Sukor(lumut)/ Kumar	7:00 AM

During 23-29 July 2007

Bus	From Ipoh				No of vehicle	Driver/crew	From Lumut
	Mon-Tue-Wed-Thu			Fri-Sat-Sun			
1	7:00 AM	11:00 AM	4:00 PM		ADF 8300	Sham/Jariah	
2	7:30 AM	12:00 PM	5:00 PM		AEE 5600	Anen/Sukar	
3	8:00 AM	1:00 PM	5:30 PM		ACA 1100	Ravi/Dahalan	7:50 PM *)
4	9:00 AM	2:00 PM			ABR 8500	Sara/Ibrahim	
5	10:00 AM	3:00 PM		7:30 PM	ACX 600	Saari/Rahman	7:30 AM
6	8:30 AM	1:30 PM	6:00 PM		AEX 7800	Sukor(lumut)/ Kumar	6:20 AM
7	9:30 AM	2:30 PM	7:00 PM		ABV 1800	Alex/Badio	7:00 AM

Note: A driver hold the same bus (no of vehicle) in different week
maximum 6 trips per bus or 3 pairs trip (round trip)
*) Friday-Saturday-Sunday

B.4 Time table (schedule) of bus departure

Vehicle block	Leave Ipoh	Arrive Lumut	Leave Lumut	Arrive Ipoh
Shift 1				
1	7:00 AM	8:50 AM	9:00 AM	10:50 AM
2	7:30 AM	9:20 AM	9:30 AM	11:20 AM
3	8:00 AM	9:50 AM	10:00 AM	11:50 AM
4	8:30 AM	10:20 AM	10:30 AM	12:20 PM
5	9:00 AM	10:50 AM	11:00 AM	12:50 PM
6	9:30 AM	11:20 AM	11:30 AM	1:20 PM
7	10:00 AM	11:50 AM	12:00 PM	1:50 PM
Shift 2				
1	11:00 AM	12:50 PM	1:00 PM	2:50 PM
2	12:00 PM	1:50 PM	2:00 PM	3:50 PM
3	1:00 PM	2:50 PM	3:00 PM	4:50 PM
4	1:30 PM	3:20 PM	3:30 PM	5:20 PM
5	2:00 PM	3:50 PM	4:00 PM	5:50 PM
6	2:30 PM	4:20 PM	4:30 PM	6:20 PM
7	3:00 PM	4:50 PM	5:00 PM	6:50 PM
Shift 3				
1	4:00 PM	5:50 PM	6:00 PM	7:50 PM
2	5:00 PM	6:50 PM	7:00 PM	8:50 PM
3	5:30 PM	7:20 PM	7:50 PM	9:10 PM
4	6:00 PM	7:50 PM	6:20 AM	8:10 AM
5	-	-	-	-
6	7:00 PM	8:50 PM	7:00 AM	8:50 AM
7	7:30 PM	9:20 PM	7:30 AM	9:20 AM

B.5 Operating cost per bus per day

Operator: Perak Roadways Sdn. Bhd.
No Bas: ABP2200
Tarikh: 18-Jan-2007

Collection	Ringgit
1. Kaunter Ipoh	10
2. Collection Dalam Bas	20
3. Kaunter Lumut	40
4. Kaunter Bota	50
5. Agen Sitiawan	20
Jumlah 1 =	140

Bilangan	Perkara	Ringgit
1	Minyak disel	351
2	Gaji	166
3	Pinjaman (Finance)	300
4	Spare part	150
5	Tayar & Tiub	35
6	Insuran	30
7	Road tax	8
8	Bus cleaning	5
9	Tol (plus)	56
10	KWSP & EPF	5
11	Rental kaunter	20
12	Telefon, elctrik, air	10
13	Lain-lain	20
	Jumlah 2 =	1156

Perbelanjaan sebuah bas sehari (Jumlah 1 + 2) =	1,296

APPENDIX C:
Statistical Tables

C.1 Table of F-Distribution

F Table for alpha=.05

df2/df1	1	2	3	4	5	6	7	8	9	10	12	15
1	161.4476	199.5000	215.7073	224.5832	230.1619	233.9860	236.7684	238.8827	240.5433	241.8817	243.9060	245.9499
2	18.5128	19.0000	19.1643	19.2468	19.2964	19.3295	19.3532	19.3710	19.3848	19.3959	19.4125	19.4291
3	10.1280	9.5521	9.2766	9.1172	9.0135	8.9406	8.8867	8.8452	8.8123	8.7855	8.7446	8.7029
4	7.7086	6.9443	6.5914	6.3882	6.2561	6.1631	6.0942	6.0410	5.9988	5.9644	5.9117	5.8578
5	6.6079	5.7861	5.4095	5.1922	5.0503	4.9503	4.8759	4.8183	4.7725	4.7351	4.6777	4.6188
6	5.9874	5.1433	4.7571	4.5337	4.3874	4.2839	4.2067	4.1468	4.0990	4.0600	3.9999	3.9381
7	5.5914	4.7374	4.3468	4.1203	3.9715	3.8660	3.7870	3.7257	3.6767	3.6365	3.5747	3.5107
8	5.3177	4.4590	4.0662	3.8379	3.6875	3.5806	3.5005	3.4381	3.3881	3.3472	3.2839	3.2184
9	5.1174	4.2565	3.8625	3.6331	3.4817	3.3738	3.2927	3.2296	3.1789	3.1373	3.0729	3.0061
10	4.9646	4.1028	3.7083	3.4780	3.3258	3.2172	3.1355	3.0717	3.0204	2.9782	2.9130	2.8450
11	4.8443	3.9823	3.5874	3.3567	3.2039	3.0946	3.0123	2.9480	2.8962	2.8536	2.7876	2.7186
12	4.7472	3.8853	3.4903	3.2592	3.1059	2.9961	2.9134	2.8486	2.7964	2.7534	2.6866	2.6169
13	4.6672	3.8056	3.4105	3.1791	3.0254	2.9153	2.8321	2.7669	2.7144	2.6710	2.6037	2.5331
14	4.6001	3.7389	3.3439	3.1122	2.9582	2.8477	2.7642	2.6987	2.6458	2.6022	2.5342	2.4630
15	4.5431	3.6823	3.2874	3.0556	2.9013	2.7905	2.7066	2.6408	2.5876	2.5437	2.4753	2.4034
16	4.4940	3.6337	3.2389	3.0069	2.8524	2.7413	2.6572	2.5911	2.5377	2.4935	2.4247	2.3522
17	4.4513	3.5915	3.1968	2.9647	2.8100	2.6987	2.6143	2.5480	2.4943	2.4499	2.3807	2.3077
18	4.4139	3.5546	3.1599	2.9277	2.7729	2.6613	2.5767	2.5102	2.4563	2.4117	2.3421	2.2686
19	4.3807	3.5219	3.1274	2.8951	2.7401	2.6283	2.5435	2.4768	2.4227	2.3779	2.3080	2.2341
20	4.3512	3.4928	3.0984	2.8661	2.7109	2.5990	2.5140	2.4471	2.3928	2.3479	2.2776	2.2033
21	4.3248	3.4668	3.0725	2.8401	2.6848	2.5727	2.4876	2.4205	2.3660	2.3210	2.2504	2.1757
22	4.3009	3.4434	3.0491	2.8167	2.6613	2.5491	2.4638	2.3965	2.3419	2.2967	2.2258	2.1508
23	4.2793	3.4221	3.0280	2.7955	2.6400	2.5277	2.4422	2.3748	2.3201	2.2747	2.2036	2.1282
24	4.2597	3.4028	3.0088	2.7763	2.6207	2.5082	2.4226	2.3551	2.3002	2.2547	2.1834	2.1077
25	4.2417	3.3852	2.9912	2.7587	2.6030	2.4904	2.4047	2.3371	2.2821	2.2365	2.1649	2.0889
26	4.2252	3.3690	2.9752	2.7426	2.5868	2.4741	2.3883	2.3205	2.2655	2.2197	2.1479	2.0716
27	4.2100	3.3541	2.9604	2.7278	2.5719	2.4591	2.3732	2.3053	2.2501	2.2043	2.1323	2.0558
28	4.1960	3.3404	2.9467	2.7141	2.5581	2.4453	2.3593	2.2913	2.2360	2.1900	2.1179	2.0411
29	4.1830	3.3277	2.9340	2.7014	2.5454	2.4324	2.3463	2.2783	2.2229	2.1768	2.1045	2.0275
30	4.1709	3.3158	2.9223	2.6896	2.5336	2.4205	2.3343	2.2662	2.2107	2.1646	2.0921	2.0148
40	4.0847	3.2317	2.8387	2.6060	2.4495	2.3359	2.2490	2.1802	2.1240	2.0772	2.0035	1.9245
60	4.0012	3.1504	2.7581	2.5252	2.3683	2.2541	2.1665	2.0970	2.0401	1.9926	1.9174	1.8364
120	3.9201	3.0718	2.6802	2.4472	2.2899	2.1750	2.0868	2.0164	1.9588	1.9105	1.8337	1.7505
inf	3.8415	2.9957	2.6049	2.3719	2.2141	2.0986	2.0096	1.9384	1.8799	1.8307	1.7522	1.6664

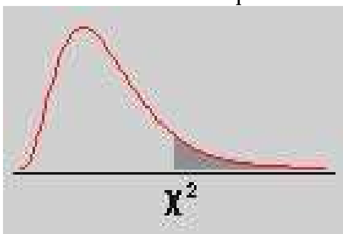
F Table for alpha=.05 (continued)

df2/df1	20	24	30	40	60	120	INF
1	248.0131	249.0518	250.0951	251.1432	252.1957	253.2529	254.3144
2	19.4458	19.4541	19.4624	19.4707	19.4791	19.4874	19.4957
3	8.6602	8.6385	8.6166	8.5944	8.5720	8.5494	8.5264
4	5.8025	5.7744	5.7459	5.7170	5.6877	5.6581	5.6281
5	4.5581	4.5272	4.4957	4.4638	4.4314	4.3985	4.3650
6	3.8742	3.8415	3.8082	3.7743	3.7398	3.7047	3.6689
7	3.4445	3.4105	3.3758	3.3404	3.3043	3.2674	3.2298
8	3.1503	3.1152	3.0794	3.0428	3.0053	2.9669	2.9276
9	2.9365	2.9005	2.8637	2.8259	2.7872	2.7475	2.7067
10	2.7740	2.7372	2.6996	2.6609	2.6211	2.5801	2.5379
11	2.6464	2.6090	2.5705	2.5309	2.4901	2.4480	2.4045
12	2.5436	2.5055	2.4663	2.4259	2.3842	2.3410	2.2962
13	2.4589	2.4202	2.3803	2.3392	2.2966	2.2524	2.2064
14	2.3879	2.3487	2.3082	2.2664	2.2229	2.1778	2.1307
15	2.3275	2.2878	2.2468	2.2043	2.1601	2.1141	2.0658
16	2.2756	2.2354	2.1938	2.1507	2.1058	2.0589	2.0096
17	2.2304	2.1898	2.1477	2.1040	2.0584	2.0107	1.9604
18	2.1906	2.1497	2.1071	2.0629	2.0166	1.9681	1.9168
19	2.1555	2.1141	2.0712	2.0264	1.9795	1.9302	1.8780
20	2.1242	2.0825	2.0391	1.9938	1.9464	1.8963	1.8432
21	2.0960	2.0540	2.0102	1.9645	1.9165	1.8657	1.8117
22	2.0707	2.0283	1.9842	1.9380	1.8894	1.8380	1.7831
23	2.0476	2.0050	1.9605	1.9139	1.8648	1.8128	1.7570
24	2.0267	1.9838	1.9390	1.8920	1.8424	1.7896	1.7330
25	2.0075	1.9643	1.9192	1.8718	1.8217	1.7684	1.7110
26	1.9898	1.9464	1.9010	1.8533	1.8027	1.7488	1.6906
27	1.9736	1.9299	1.8842	1.8361	1.7851	1.7306	1.6717
28	1.9586	1.9147	1.8687	1.8203	1.7689	1.7138	1.6541
29	1.9446	1.9005	1.8543	1.8055	1.7537	1.6981	1.6376
30	1.9317	1.8874	1.8409	1.7918	1.7396	1.6835	1.6223
40	1.8389	1.7929	1.7444	1.6928	1.6373	1.5766	1.5089
60	1.7480	1.7001	1.6491	1.5943	1.5343	1.4673	1.3893
120	1.6587	1.6084	1.5543	1.4952	1.4290	1.3519	1.2539
inf	1.5705	1.5173	1.4591	1.3940	1.3180	1.2214	1.0000

Source: StatSoft, Inc., STATISTICA (data analysis software system), Version 7, 2004.

C.2 Chi-Square Table

Right tail areas for the Chi-square Distribution



df\area	.995	.990	.975	.950	.900	.750	.500	.250	.100	.050	.025	.010	.005
1	0.00004	0.00016	0.00098	0.00393	0.01579	0.10153	0.45494	1.32330	2.70554	3.84146	5.02389	6.63490	7.87944
2	0.01003	0.02010	0.05064	0.10259	0.21072	0.57536	1.38629	2.77259	4.60517	5.99146	7.37776	9.21034	10.59663
3	0.07172	0.11483	0.21580	0.35185	0.58437	1.21253	2.36597	4.10834	6.25139	7.81473	9.34840	11.34487	12.83816
4	0.20699	0.29711	0.48442	0.71072	1.06362	1.92256	3.35669	5.38527	7.77944	9.48773	11.14329	13.27670	14.86026
5	0.41174	0.55430	0.83121	1.14548	1.61031	2.67460	4.35146	6.62568	9.23636	11.07050	12.83250	15.08627	16.74960
6	0.67573	0.87209	1.23734	1.63538	2.20413	3.45460	5.34812	7.84080	10.64464	12.59159	14.44938	16.81189	18.54758
7	0.98926	1.23904	1.68987	2.16735	2.83311	4.25485	6.34581	9.03715	12.01704	14.06714	16.01276	18.47531	20.27774
8	1.34441	1.64650	2.17973	2.73264	3.48954	5.07064	7.34412	10.21885	13.36157	15.50731	17.53455	20.09024	21.95495
9	1.73493	2.08790	2.70039	3.32511	4.16816	5.89883	8.34283	11.38875	14.68366	16.91898	19.02277	21.66599	23.58935
10	2.15586	2.55821	3.24697	3.94030	4.86518	6.73720	9.34182	12.54886	15.98718	18.30704	20.48318	23.20925	25.18818
11	2.60322	3.05348	3.81575	4.57481	5.57778	7.58414	10.34100	13.70069	17.27501	19.67514	21.92005	24.72497	26.75685
12	3.07382	3.57057	4.40379	5.22603	6.30380	8.43842	11.34032	14.84540	18.54935	21.02607	23.33666	26.21697	28.29952
13	3.56503	4.10692	5.00875	5.89186	7.04150	9.29907	12.33976	15.98391	19.81193	22.36203	24.73560	27.68825	29.81947
14	4.07467	4.66043	5.62873	6.57063	7.78953	10.16531	13.33927	17.11693	21.06414	23.68479	26.11895	29.14124	31.31935
15	4.60092	5.22935	6.26214	7.26094	8.54676	11.03654	14.33886	18.24509	22.30713	24.99579	27.48839	30.57791	32.80132
16	5.14221	5.81221	6.90766	7.96165	9.31224	11.91222	15.33850	19.36886	23.54183	26.29623	28.84535	31.99993	34.26719
17	5.69722	6.40776	7.56419	8.67176	10.08519	12.79193	16.33818	20.48868	24.76904	27.58711	30.19101	33.40866	35.71847
18	6.26480	7.01491	8.23075	9.39046	10.86494	13.67529	17.33790	21.60489	25.98942	28.86930	31.52638	34.80531	37.15645
19	6.84397	7.63273	8.90652	10.11701	11.65091	14.56200	18.33765	22.71781	27.20357	30.14353	32.85233	36.19087	38.58226
20	7.43384	8.26040	9.59078	10.85081	12.44261	15.45177	19.33743	23.82769	28.41198	31.41043	34.16961	37.56623	39.99685
21	8.03365	8.89720	10.28290	11.59131	13.23960	16.34438	20.33723	24.93478	29.61509	32.67057	35.47888	38.93217	41.40106
22	8.64272	9.54249	10.98232	12.33801	14.04149	17.23962	21.33704	26.03927	30.81328	33.92444	36.78071	40.28936	42.79565
23	9.26042	10.19572	11.68855	13.09051	14.84796	18.13730	22.33688	27.14134	32.00690	35.17246	38.07563	41.63840	44.18128
24	9.88623	10.85636	12.40115	13.84843	15.65868	19.03725	23.33673	28.24115	33.19624	36.41503	39.36408	42.97982	45.55851
25	10.51965	11.52398	13.11972	14.61141	16.47341	19.93934	24.33659	29.33885	34.38159	37.65248	40.64647	44.31410	46.92789
26	11.16024	12.19815	13.84390	15.37916	17.29188	20.84343	25.33646	30.43457	35.56317	38.88514	41.92317	45.64168	48.28988
27	11.80759	12.87850	14.57338	16.15140	18.11390	21.74940	26.33634	31.52841	36.74122	40.11327	43.19451	46.96294	49.64492
28	12.46134	13.56471	15.30786	16.92788	18.93924	22.65716	27.33623	32.62049	37.91592	41.33714	44.46079	48.27824	50.99338
29	13.12115	14.25645	16.04707	17.70837	19.76774	23.56659	28.33613	33.71091	39.08747	42.55697	45.72229	49.58788	52.33562
30	13.78672	14.95346	16.79077	18.49266	20.59923	24.47761	29.33603	34.79974	40.25602	43.77297	46.97924	50.89218	53.67196

Source: StatSoft, Inc., STATISTICA (data analysis software system), Version 7, 2004.

APPENDIX D:
Standards and References

D.1 World Bank Standard

D.1.1 Operational performance indicators

No.	Components and Criteria		Values
1.	Passengers volumes		
	Average number of passengers per operating bus per day		
	Type of bus	Crush capacity	
	- Single deck	80	1,000-1,200
	- Single deck	100	1,200-1,500
	- Single or double deck	120	1,500-1,800
	- Articulated or double deck	160	2,000-2,400
2.	Fleet utilization		
	Buses in service during the peak, as a percentage of the total fleet:		80-90
3.	Distance traveled by buses		
	Average kilometers per bus per day		210-260
4.	Breakdown in service		
	As a percentage of buses in operation:		8-10
5.	Fuel consumption		
	Liters per 100 kilometers		
		Minibuses	20-25
		Buses	25-50
6.	Staff ratios		
	Staff per operating bus:		
		Total staff	3-8
		Administrative	0.3-0.4
		Maintenance staff	0.5-1.5
7.	Accident rate		
	Accidents per 100,000 bus kilometers:		1.5-3.0
8.	Dead mileage		
	Percentage length of bus journey not earning revenue:		0.6-1.0
9.	Cost of bus services		
	Total cost (operating cost, depreciation and interest) per passenger-kilometer		
		Mixed traffic:	US c 2-5
		Segregated busways:	5-8
10.	Operating ratio		
	Total revenue divided by operating cost including depreciation		1.05:1-1.8:1

Source: World Bank Technical Paper Number 68: Urban Transport Series

D.1.2 Quality of service indicators

No.	Criteria and Measurements	Values	Unit
1	Waiting time		
	Passenger waiting time at bus stops		
	- Average	5-10	minutes
	- Maximum	10-20	minutes
2.	Walking distance to bus stops		
	- Dense urban areas	300-500	m
	- Low-density urban areas	500-1,000	m
3.	Interchanges between routes and services		
	The number of times a passenger has to change buses or other mode on a journey to or from work:		
	- Average	0-1	
	- Maximum (less than 10% of commuters)	2	
4.	Journey times		
	Hours traveling each day to and from work:		
	- Average	1.0-1.5	
	- Maximum	2-3	
	Journey speeds of buses:		
	- Dense areas in mixed traffic	10-12	km/h
	- Bus-only lanes	15-18	km/h
	- Low-density areas	25	km/h
5.	Travel expenditure		
	Household expenditure on travel as a percentage of household income:	10	

Source: World Bank Technical Paper Number 68: Urban Transport Series

D.1.3 Performance indicator of operational bus service

No.	Criteria	Parameter	Standard
1.	Rate of operated-available vehicle ratio	Ratio between number of operating vehicle and number of planned vehicle or available (%)	80-90
2.	Utility of vehicle	Average of traveled distance every day (km/day)	210-260
3.	Number of passenger	Number of passenger loaded each bus per day (persons/bus/day)	440-525
4.	Productivity of management	- number of administrative staff / bus	0.3-0.4
		- number of workshop staff / bus	0.5-1.5
		- number of total staff / bus	3-8
5.	Rate of accident	Number of accident each 100.000 km traveled distance (accident/100.000 bus-km)	1.5-3
6.	Rate of upholding or preservation	The percentage of number of bus in preservation to the total bus operated (%)	8-10
7.	Fuel consumption	The volume of fuel consumed each bus per 100 km of travel distance (liter/bus-100 km)	25-50
8.	Operating ratio	Ratio between revenue and operating cost (depreciation included)	1.05-1.08
9.	Load factor	Ratio between number of passenger and capacity of bus (number of seats) in a period of time (%)	70
10.	Number of transferred passenger	- no transfers/transit	> 50%
		- 2 transfers (twice)	< 10%

Source: World Bank Technical Paper Number 68: Urban Transport Series

D.1.4 Performance and characteristics of regular bus (RB)

No	Parameters	Units	Standard
1.	Vehicle capacity	seats/bus	40-120
2.	Frequency	bus/h	60-180
3.	Passenger capacity of route	pass/h	2,400-8,000
4.	Operating speed	km/h	15-25
5.	Lane width (one-way)	m	3.00-3.65
6.	Vehicle control	-	man/vis
7.	Reliability	-	low-med
8.	Safety	-	med
9.	Station spacing	m	200-500

Note: man : manual, vis : visual, med : medium

Source: Vuchic (1981) - Adapted for regular bus

D.2 Indicators of Automobile Dependency

Indicator	Description	Low Dependency	Medium Dependency	High Dependency
Vehicle Ownership	Per capita motor vehicle ownership (usually measured per 1,000 population).	Less than 250 per 1,000 pop.	250 to 450	More than 450
Vehicle Travel	Per capita annual motor vehicle mileage.	Less than 4,000 miles (6,500 km)	4,000 to 8,000 miles (6,500 to 13,000 km)	More than 8,000 miles (13,000 km)
Vehicle Trips	Automobile trips as a portion of total commuting trips.	Less than 50%	50 to 75%	More than 75%
Quality of Transportation Alternatives	Convenience, speed, comfort, affordability and prestige of walking, cycling and public transit relative to driving.	Alternative modes are of competitive quality.	Alternative modes are somewhat inferior.	Alternative modes are very inferior.
Relative Mobility of Non-Drivers	Mobility of personal travel by non-drivers compared with drivers.	Non-drivers are not severely disadvantaged.	Non-drivers are moderately disadvantaged.	Non-drivers are severely disadvantaged.
Market Distortions Favoring Automobile Use	Relative advantage provided to automobile transportation over other modes in planning, funding, tax policy, etc.	Minimal bias favoring automobile travel.	Moderate bias favoring automobile travel.	Significant bias favoring automobile travel.

Source: adapted from Victoria Transport Policy Institute (2002) Automobile Dependency, Transport Demand Management Encyclopedia, http://www.vtpi.org/tdm/tdm100.htm.

APPENDIX E:
List of Publications

E.1 Journal Articles

1. **Suwardo**, Napiah, M. and Kamaruddin, I. 2010 "ARIMA Models for Bus Travel Time Prediction", *The Journal of the Institution of Engineers*, Vol. 71, No.2, ISSN: 0126-513X, pp. 49-58, June 2010, Kuala Lumpur, Malaysia. (In Editor with Ref No: IEM/PUB/356/09 Date: 6 March 2009, Modify with Ref No: IEM/PUB/292/09 Date: 14 August 2009).

2. **Suwardo**, Napiah, M., Kamaruddin, I., and Wahyunggoro, O. 2010. "Bus Travel Time Prediction in the Mixed Traffic Based on Statistica Neural Network", *Jurnal Transportasi*, Vol.10, No.1, ISSN: 1411-2442, pp. 33-42, April 2010, Forum Studi Transportasi antar Perguruan Tinggi (FSTPT), Bandung, Indonesia.

3. **Suwardo,** Napiah, M. and Kamaruddin, I. 2010. "Ridership Factors Change and Bus Service Demand Sensitivity Assessment of the Fixed-Route Bus Service for Short-term Action Plan", *International Journal of Civil & Environmental Engineering (IJCEE), Volume 10 Issue 02*, IJCEE/IJENS 100702-4949: Acknowledgement of Paper (February 5, 2010), International Journals of Engineering & Sciences, Email: editor@ijens.org, Website: www.ijens.org.

4. **Suwardo**, Napiah, M. and Kamaruddin, I. 2009 "On-Time Performance and Service Regularity of Stage Buses in Mixed Traffic", *International Journal of Business, Economics, Finance and Management Sciences*, Vol. 1 No. 3, pp. 176-183, http://www.waset.org/journals/ijbefms/v1/v1-3-22.pdf, ISSN: 2073-0519, World Academy of Science, Engineering and Technology, Paris, France.

5. **Suwardo**, Napiah, M. and Kamaruddin, I. 2008 "Punctuality and Expected Waiting Time of Stage Buses in the Mixed Traffic", *Jurnal Transportasi*, Edisi Khusus, Vol.8, No.3, pp. 213-226, ISSN: 1411-2442, October 2008, Forum Studi Transportasi antar Perguruan Tinggi (FSTPT), Bandung, Indonesia.

E.2 Conference Proceedings

1. **Suwardo,** Napiah, M. and Kamaruddin, I. 2010. "Trip Distribution of Bus Service Passengers by Using Gravity Models", *Proceeding of International Conference on Sustainable Building and Infrastructure (ICSBI2010)*, Kuala Lumpur, Malaysia, 15th-17th June 2010.

2. **Suwardo,** Napiah, M. and Kamaruddin, I. 2009. "Determinant Variables of Travel Time and Bus Travel Time Prediction: Case Study Ipoh-Lumut Corridor Intercity

Regular Bus Service in Malaysia", *Proceeding of the Eastern Asia Society for Transportation Studies*, Vol.7, Surabaya, Indonesia, 16th-19th November 2009.

3. **Suwardo**, Napiah, M., Kamaruddin, I., and Wahyunggoro, O. 2009. "Bus Travel Time Prediction in the Mixed Traffic by Using Statistica Neural Network", *Proceeding of Simposium XII FSTPT*, ISBN: 979-95721-2-12, Universitas Kristen Petra, Surabaya, Indonesia, 14th November 2009.

4. **Suwardo,** Napiah, M. and Kamaruddin, I. 2009. "ARIMA Models for Bus Travel Time Prediction", *Proceeding of National Postgraduate Conference on Engineering, Science and Technology (NPC 2009)*, Universiti Teknologi PETRONAS (UTP), Perak, Malaysia, 25th-26th March 2009.

5. **Suwardo,** Napiah, M. and Kamaruddin, I. 2008. "Review on Motorization and Use of Public Transport in Perak Malaysia - Realities and Challenges", *Proceeding of 2nd International Conference on Built Environtment in Developing Countries (ICBEDC 2008)*, ISBN: 978-983-3986-40-8, Universiti Sains Malaysia (USM), Pinang, Malaysia, 3rd–4th December 2008.

6. **Suwardo,** Napiah, M. and Kamaruddin, I. 2008. "On-Time Performance and Service Regularity of Stage Buses in Mixed Traffic", *Proceeding of National Postgraduate Conference on Engineering, Science and Technology (NPC 2008)*, Universiti Teknologi PETRONAS (UTP), Perak, Malaysia, 31st March 2008.

7. **Suwardo,** Napiah, M. and Kamaruddin, I. 2007. "Bus Operation Characteristics and Performance Indicators as a Preliminary Study in Promoting Public Transport: A Case Study Based on the Ipoh-Lumut Corridor in Perak", *Proceeding of Sidang Kebangsaan Ke-4 Kejuruteraan Awam: 50 Tahun Selepas Kemerdekaan (AWAM'07)*, ISBN: 978-983-42190-0-0, Universiti Sains Malaysia (USM), Langkawi, Malaysia, 29th-31st May 2007.